COMBUSTION

EVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

6, No. 10 APRIL, 1935 25c a copy

Mill in power plant supplying Hastings, Nebraska

Removal of Smoke and Acid Constituents from Flue Gases

The Derivation and Use of a Boiler Loading Schedule

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME SIX NUMBER TEN

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FOR APRIL 1935

FEATURE ARTICLES

EDITORIAL

DEPARTMENTS

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EDITORIAL

Power Survey Reveals Inadequate Capacity

THE report of the National Power Survey, ordered by the President in August 1933, was released in preliminary form on April first. This survey covered nearly four hundred privately owned operating companies, representing ninety-three per cent of the installed central-station capacity, in addition to a number of the more important municipal plants.

In the main, the results confirm what has long been suspected by many engineers regarding the inadequacy of present capacity to meet demands incident to a resumption of pre-depression industrial activity together with the constantly increasing domestic and small commerical light and power load. Opinion to the contrary has sometimes been influenced by a local or sectional viewpoint, or by the belief that the old plants are fully capable of handling the peaks. Others contend that the government is trying to justify its huge expenditure for hydro projects, although most of these so far are in sections that can have little effect on the country as a whole.

Early construction of three to four million kilowatts capacity is imperative, according to the survey; this need being accentuated by the existence of much obsolete steam-plant equipment. Fifty-six per cent of the present capacity is ten or more years old, eleven per cent twenty years or more, and of the total only eighty-six per cent is regarded as dependable to meet present demands. When it is considered that most of the highly efficient stations have been built within the last ten years, the statement in the report, that two million kilowatts is due to be scrapped, seems to have some basis.

It will be recalled that from 1920 to 1930 central station capacity in this country increased at a rate of approximately ten per cent per year, whereas during the last five years a total of only about five per cent has been added; and this figure includes several large hydro projects upon which construction was begun prior to 1930. The decided drop in load during the early years of the depression provided justification at the time for the contention that central-station capacity was more than adequate. However, with the total load now practically back to the 1929–1930 level, despite only partial industrial recovery, and most of the equipment five years older, the time has arrived again to act upon a projection of the capacity and load curves. Some companies have tentative plans for extension or replacement already underway, but, as it will require from one to two years to put these into effect, the situation may become pressing.

That there has been so little new construction in the utility field is attributable, not to lack of a full appreciation of these facts, but to the combination of difficulties lately confronting the industry, such as mounting taxation, pending holding company legislation, financing problems, rate reductions and threatened federal and municipal competition. However, load demands will not await a solution of these problems and it behooves the industry to guard against a situation susceptible to interpretation that privately owned systems are unable or unwilling to meet the growing load demands.

A significant statement in the report is that "selection of sites for hydro and steam plants, to be developed either by private or public agencies, should take into consideration not only the pertinent engineering and economic factors but also essential considerations of broad national policies," and federal supervision of the construction of these plants and facilities is urged. It is therefore likely that legislation embodying these recommendations will be proposed. The Power Authority in New York State is already advocating a system patterned after the British "grid."

In this connection it is pertinent to recall the situation in England where the public power supply, although privately owned, is very closely supervised by a government commission. With the development of the "grid" system, comprising about ninety-eight per cent of the supply, extensions to existing generating stations, the location of new stations and the flow of electricity into and out of the "grid" are passed upon by this governmental body.

The load conditions that have obtained in England parallel, in certain respects, those in this country. Following several years of industrial depression, the domestic load there made substantial gains and then the industrial load began to return to normalcy; meanwhile little new capacity had been added. Anticipating a shortage in capacity, the government initiated extensions to existing stations as well as a number of new stations at centers that would best serve the requirements of the "grid." These are now being made, but the urgency of the situation, according to a well-known British engineer now in this country, has precluded taking full advantage of what otherwise would have represented progressive development in power station practice. Moreover, according to our informant, the transmission system of the "grid" has placed certain restrictions on unit generating capacity which in some instances have not been in line with best individual station economy.

Whatever the future may hold in the nature of federal coordination of our national power supply, the central station industry is still free to proceed along lines dictated by engineering and economic considerations.

Relative Purchase Values of COAL

By C. G. KLOPP, Steam Engineer

The Champion Fibre Co., Canton, N. C.

On the basis that the most economical coal to buy is that which will produce the greatest amount of steam per dollar spent, the accompanying chart, in use by the Champion Fibre Company, forms a convenient method of determining relative purchase values of coal.

A QUESTION of vital importance to the plant manager is whether or not the coal used for plant operation is being purchased on the most economical basis. The consideration of this question involves an interesting problem which deals with the saving of valuable dollars. There are many plants in operation today using one or several grades of coal which has been purchased strictly on a price per ton basis. In many cases, after making the proper analysis of the problem, it has been developed that the coal with the lowest delivered price per ton is not the cheapest for the plant. Weekly savings amounting to hundreds of dollars might easily be realized by coal purchases according to the method here suggested.

This method is based on the opinion, that the most economical coal to buy is that with which the greatest amount of steam can be produced per dollar spent. For this purpose, laboratory determinations of the Btu per pound of dry coal, and the per cent moisture in the coal as received, are in most cases all that will be required. There are, however, certain conditions which might make it necessary to obtain a laboratory determination on the ash content of the coal. For pulverized coal plants, located near a community which may consider the fly ash a nuisance, and make it necessary to use a mechanical or an electrical method of ash precipitation, the low ash content coal will certainly prove to be quite an advantage. A lower maintenance of the pulverizing equipment, the burners and the induced-draft fans will help justify a slight increase in the coal price of a low ash content coal.

The first consideration, however, should be: how much steam can be produced per dollar paid for coal, or what amounts to the same thing, how many Btu's are bought per penny? In order to illustrate the purpose of this discussion, and also to show how the accompanying chart may be used, we will assume the following example:

Suppose that during a week a plant has consumed twenty cars of coal which came from three different mines. Thirteen cars came from mine A and were purchased at a delivered price of \$3.20 per ton. Five cars came from mine B and cost \$3.35 per ton. The remaining two cars came from mine C and cost \$3.40 per ton. Laboratory analyses of these three coals show:

	Btu per Pound of Dry Coal	Per cent Moisture
Coal from Mine A	13,000	7.5
B	13,200	3.0
C	14,000	5.0

From the information so far obtained, a table similar to the one following will be very helpful in analyzing any particular problem, and will show at a glance the relative values of the different kinds of coal used.

$$\text{Item } 7 = \frac{\text{Item } 1 \times 2000}{\text{Item } 6} \qquad \text{Item } 8 = \frac{\text{Item } 3 \times 2000}{\text{Item } 6}$$

$$\text{Item } 11 = \frac{\text{Item } 3 \times 2000}{78{,}235}$$

Item 14 = Item 13 × Item 12 × 50 (One car is assumed to hold 50 tons)

		A	B	C
1.	Btu per pound of dry coal	13,000	13,200	14,000
2.	Per cent moisture	7.5	3.0	5.0
3.	Btu per pound of coal, as fired	12,025	12,804	13,300
4.	Price per ton at the mine			
5.	Freight rate per ton			
6.	Price per ton delivered	\$3.20	\$3.35	\$3.40
7.	Btu per penny (dry basis)	81,250	78,806	82,353
8.	Btu per penny (as fired)	75,156	76,442	78,235
9.	Relative value (dry basis)	No. 2	No. 3	No. 1
10.	Relative value (as fired basis)	No. 3	No. 2	No. 1
11.	Price to equal No. 1 coal	\$3.07	\$3.27	\$3.40
12.	Loss per ton based on No. 1	\$0.13	\$0.08	\$0.00
13.	Number of cars used	13	5	2
14.	Loss per week based on No. 1	\$84.50	\$20.00	\$0.00
15.	Total loss for the week		\$104.50	

From the point of view of the plant manager or the coal buyer, the Btu purchased per penny on the "as fired" basis is the figure to be used in determining the relative values of the various coals. The coal dealer will probably ask for a comparison of his coal with the others on the dry basis, hence they are given.

In this example, it is to be noted that the cheapest coal per ton is not the best buy. In order to equal the \$3.40 coal, that from mine A would have to be reduced to \$3.07.

The accompanying chart has been worked up for the benefit of the coal buyer or the dealer in arriving at the Btu per penny values for the various grades of coal. Suppose the chart is used to find the Btu per penny values for the coal in the above example from mine C having 14,000 Btu per pound (dry basis) and 5.0 per cent moisture. Starting at the left-hand scale with 14,000 Btu follow this line vertically until it intersects the 5 per cent moisture line. From this point of intersection follow to the right on the horizontal line where the Btu per pound of coal as fired will be noted as 13,300, continuing on the horizontal until intersection with the \$3.40 coal cost line. From this point of intersection follow the vertical line down and read 78,250 Btu per penny.

In using the chart to find the Btu per penny for dry coal follow the same route except follow the 14,000 Btu line vertically until it intersects the 0 per cent moisture.

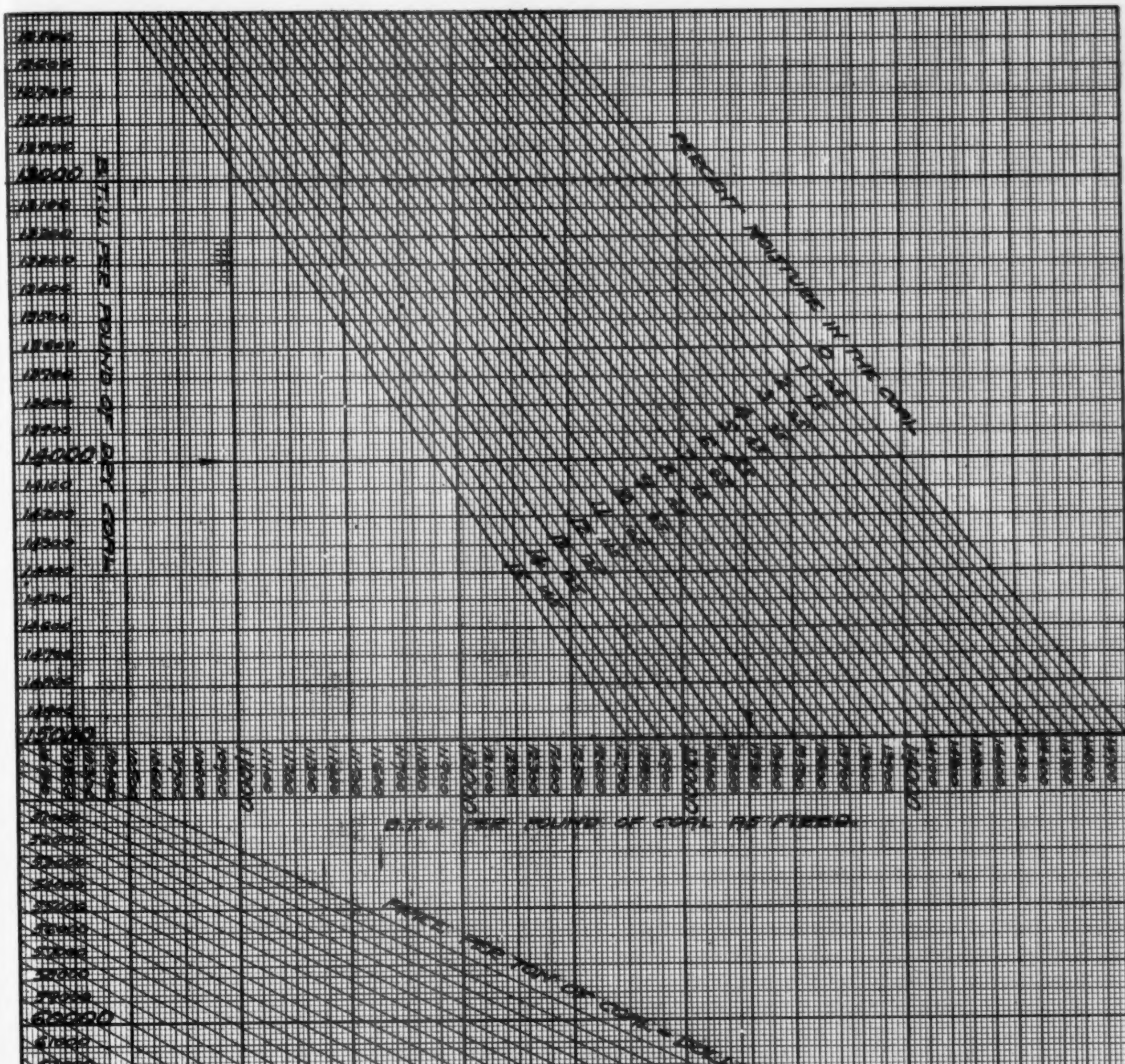


CHART TO DETERMINE THE RELATIVE PURCHASE VALUES OF COAL

Non-Effluent Water Process Removal of Smoke and Acid Constituents from Flue Gases by a

By DR. J. L. PEARSON,
G. NONHEBEL and
P. H. N. ULANDER

Excerpts from a paper presented at a joint meeting of The Institute of Fuel and The Institution of Electrical Engineers at London, Eng., on January 17, 1935. The paper reviews the problem of atmospheric pollution from cinders, fly ash and sulphur fumes in stack gases and describes the Howden-I. C. I. non-effluent system of flue-gas washing which employs lime or chalk as the neutralizing agent. In this wet washing system the water is recirculated and the grit, dust and acids are separated and removed as solids, hence there is no effluent to pollute adjacent streams. Results from eighteen months, operation of a pilot plant are given which show a removal of 90 to 93 per cent of the dust, 97 to 98 per cent of the grit and 90 to 99 per cent of the acid constituents of the flue gas.

IN 1927, Parliamentary sanction for the erection of Battersea Power Station was given on condition that the best practicable means would be taken to remove the oxides of sulphur from the flue gases before the latter were emitted to the atmosphere. Similar restrictions have been made, or are being made, in connection with extensions of other power stations in the central London area.

Examples of the trend in modern requirements are given by the official specifications calling for tenders for flue gas cleaning apparatus in connection with two power stations in course of erection in urban districts, namely the specification for Swansea calling for 96 per cent, sulphur and dust elimination, and that for Fulham requiring very high dust elimination and an exit sulphur test of 0.03 gr per cu ft (equal to 50 parts of SO_2 per million by volume), with the use of coal containing 1.7 per cent. Sulphur (giving an extraction efficiency requirement of 96 per cent) for stoker-fired boilers.

The Formation of Sulphuric Acid

In addition to oxides of sulphur (mainly sulphur dioxide), oxides of nitrogen and hydrochloric acid are liberated in modern high-temperature furnaces. Oxidation of the SO_2 is promoted by sunlight, and much of the SO_2 is oxidized rapidly after absorption from the atmosphere by rain or mist, to form sulphuric acid. Thus, the combustion of 1000 tons of average coal containing, say, 1.5 per cent sulphur, leads not only to the formation of grit, dust and possibly of tarry matter, but also to the eventual formation of the following acids:

(*a*) 45 tons of sulphuric acid
(*b*) 3 to 7 tons of nitric acid (dependent upon the combustion conditions)
(*c*) 0.5 ton of hydrochloric acid

Practical remedies for preventing or reducing the emission of objectionable constituents in flue gases have in the past been confined mainly to the elimination or mitigation of grit and dust emission, although it has long been realized that the acid emission in large urban areas was attended with the more serious consequences.

Modern development in the electricity supply industry is leading to the erection of power stations burning more than 1000 tons per day of coal. Although domestic household coal consumption is estimated to be about 23 per cent of the total consumption in this country and power station consumption only 6 per cent, a domestic consumption of 1000 tons per day is equivalent to that of 70,000 houses, at 2 cwt each per week, which represents a large town covering an area of at least 5 sq miles. Spread over this area, discharged as a line source of emission (2 to 3 miles broad) and diluted with excess air of combustion to only 3 to 4 per cent CO_2, this domestic "acid" pollution is small in concentration, when compared with the local leeward concentration in the products of combustion of 1000 tons per day of coal, at 11 to 14 per cent CO_2 and discharged from an area of a few hundred square yards, that is from a virtual point source of emission. This latter emission affects atmospheric conditions appreciably for some distance on the leeward side of the chimneys, irrespective of chimney height, unless efficient flue gas cleaning is adopted.

As concerns solid particles, below about 30 to 40 microns, and the objectionable acid constituents, any attainable increase in chimney height is ineffective in

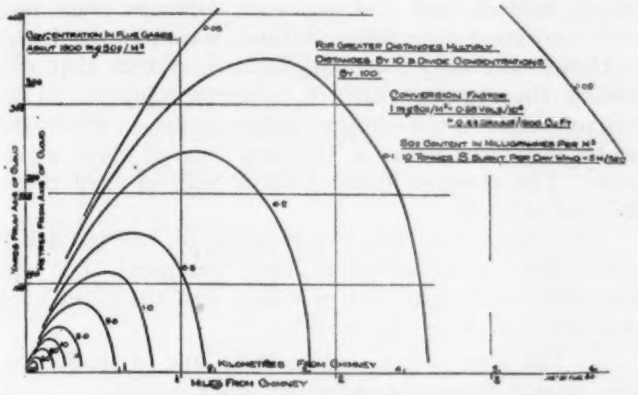


Fig. 1—Space concentration distribution of SO_2 from a point of source

preventing or reducing the results characteristic of these two types of emission, although it will mitigate slightly the ground conditions in the immediate neighborhood of the chimney. Emission should obviously be at such a height as will prevent it being brought down by downdrafts caused by the effects of the neighboring buildings or ground contour, but above this it is not necessary to go.

Considering a point source of continuous emission such as a power station chimney, and assuming a wind velocity of about 11.5 miles per hour, which is the average wind velocity, Fig. 1 shows the space concentration distribution of the SO_2 on the leeward side of the source of emission, with a power station burning 1000 tons of coal per day and the coal containing 1 per cent sulphur. For simplicity it is assumed that all the sulphur in the coal is emitted as SO_2. The curves given are typical curves and can easily be corrected for:

(*a*) other wind velocities, the concentration being inversely proportional to wind velocity;

(*b*) other sulphur contents in the coal, the concentration being directly proportional to the sulphur content;

(*c*) other coal consumptions, the concentration being directly proportional to the coal consumption or to the mass rate of SO_2 emission.

Curve for Determining Ground Conditions

The ground conditions with any height of chimney, can be determined from the curves in Fig. 1 by drawing a horizontal line with an ordinate corresponding to the height of the chimney. It will then at once be seen that under average conditions:

(*a*) the ground concentrations are quite small at distances, from the base of the chimney, greater than 20 times the height of the chimney;

(*b*) the worst ground concentration is small with a reasonable height of chimney (say, 200 ft high);

(*c*) the worst ground conditions occur at a distance of 8 to 10 chimney heights away.

The most useful curves for discussing acid and dust pollution of the atmosphere are those obtained by integrating the vertical distribution over unit area, i.e., curves representing mass distribution over unit area. The vertical integration of Fig. 1 is given in Fig. 2, which exhibits the SO_2 distribution as if collected into a single layer or roof. Height of chimney clearly has no effect on this mass distribution.

As an example for demonstrating the relative extent and effects of power station, general industrial and domestic pollution respectively, the conditions pertaining to an average but isolated industrial town can be considered. For simplicity, it is assumed that the town is generally industrial with no large well-marked residential areas, and that the power station is in the center of the town. For such a town 5 kilometers (approximately 3 miles) square (600,000 to 700,000 inhabitants), and with a power station burning 1000 tons per day of coal containing 1 per cent sulphur, the curves for mass distribution over unit area are as in Fig. 3.

With low wind velocities and with temperature inversion conditions, the SO_2 mass distributions are considerably increased. During these abnormal but too frequent weather conditions, the composite urban pollution reaches intensities which are actively damaging to buildings and injurious to health.

High Chimneys Do Not Solve the Dust Problem

Increase in chimney height may be useful for spraying grit over a wider area, but it is useless as a remedy against "acid" and "dust" emission. Chimney height should be reasonable, but need not be excessive except when inefficient apparatus for grit removal only is installed. The distinction between grit and dust is based upon settling rate versus diffusing rate. The line of demarcation is about 35 microns for average conditions, 10 microns or less (according to size of town) for urban fog conditions, and 60 to 70 microns for ordinary strong winds of 30 to 40 miles per hr. Grit settles, while dust diffuses laterally, vertically and downward.

The admission that, in urban areas, dust and acids as well as grit should be removed from power station flue gases and from those of other large point sources, before emission, and that, as a consequence some form of wet washing only can be effective in this respect, leads necessarily to the further admission that the form to be adopted, as being suitable for universal application, should not have any discharge into rivers or streams.

Discharge of Effluent Prohibited by Most Cities

In most civilized countries, there are already many exacting restrictions concerning the discharge of effluent into the water courses near and among large urban populations. The tendency to increase the scope of the restrictions is apparent almost everywhere, and as far

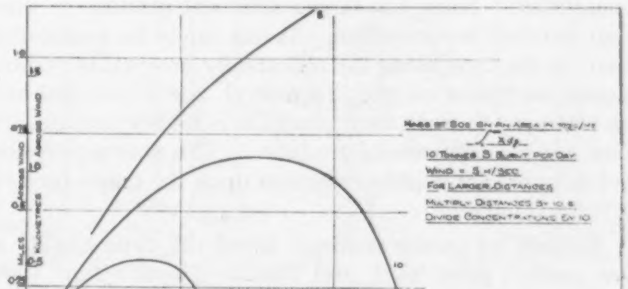


Fig. 2—Mass-over-area distribution of SO_2 from a point source of emission

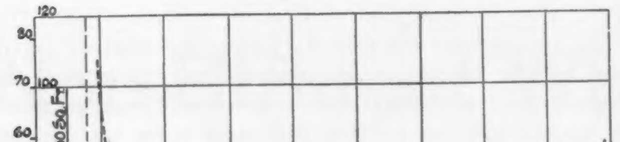


Fig. 3—Mass-over-area distribution of SO_2 as averaged over the year in urban areas

The diagram shows the integrated density in mg of SO_2 per sq meter for an industrial town 5 km square burning 3750 tons per day of coal containing 1 per cent sulphur with a power station located at its center burning 1000 tons of similar coal per day. The curves give average values for the SO_2 over the axis of the power station smoke cloud in the direction of the prevailing wind which is assumed as 5 meters per sec (11 miles per hour)

as any effluent from the wet washing of flue gases is concerned, it can be anticipated that restrictions will in the main become prohibitions, at least in the larger towns and cities. To be of universal application, therefore, the wet washing system demanded is one in which there is no liquor effluent. This means a recirculating, non-effluent water system, from which the grit, dust and acids can be separated and removed as solids.

The grit and dust will be scrubbed out of the flue gases by the recirculated water, which will be treated with some form of alkali for the purpose of scrubbing out and "fixing" the "acids." Before being able, therefore, to designate the complete type of process suitable for universal adoption, it is necessary to decide on the kind of alkali which will be everywhere available, and the use of which will be generally acceptable.

Since the solids must be separated from the circulating liquor in the system, the question arises as to whether it should be possible to provide the required form of non-effluent water system, as one producing some saleable by-product, whereby the power station could obtain a credit against charges for dust and acid removal. An answer to this question might influence the kind of alkali to be used in certain countries.

Sale of By-products Not Profitable

Various possibilities have been considered in this connection. None has shown sufficient promise to warrant detailed investigation. It can safely be postulated that for the time being the universally acceptable system should be based on the discard of the solids and not on attempts to work them, and the SO_2 they contain, up into normal commercial products. This may perhaps be better appreciated after reflection upon the major factors involved, namely,

1. Any by-products would be of the type having a low market price level, and therefore inconsistent with high conversion or capital charges. This applies irrespective of whether individual or collective production is considered.

2. An extraneous organization for production, packing, distribution and sales, with types of labor, technique, outlook and problem, each different from that now associated with power stations, would be required.

Hence, the only flue gas cleaning system that can satisfy the requirements for universal adoption in all urban areas is a non-effluent water system, in which the water is treated with the cheapest form of alkali available. The cheapest form of alkali will, in most cases, be lime or chalk.

The process for complete cleaning of flue gases will have three main sections: lime treatment, flue gas scrubbing and separation of solids, and the plant used will follow a similar classification:

1. The lime section—comprising lime or chalk storage, mixing apparatus and slurry stock tanks;

2. The flue gas scrubbing system—comprising absorption towers and main liquor recirculation system;

3. The section for separating solids—comprising settlers and filters (or centrifuges), arrangements for returning the clarified liquor to the main liquor circulating system, and the necessary plant capacity or storage for the solids prior to removal.

These three easily distinguishable sections will have the following interconnections:

(*a*) Lime slurry will pass from the lime section to the scrubbing section;

(*b*) a bleed from the main circulating system of the scrubbing section will pass to the solids section, from which

(*c*) the clarified liquor will return to the scrubbing section either directly or indirectly via the lime section.

Apart from the flue gases the only materials entering or leaving the plant will be: (in) lime and such little water as is required to make up for losses from evaporation or through the discard of wet solids; (out) separated solids, which will be wet, since it will be undesirable to dry the solids completely.

Problems Involved in Non-effluent Process

The major problems encountered in developing a non-effluent process may be summarized as follows:

1. *Absorption Surfaces.* The choice and design of a non-choking scrubber packing, with high absorption characteristics, capable of taking large liquor rates without cascading or flooding, with a suitable scaling resistance and with an optimum incidence on capital and running charges when operating with very high extraction efficiencies for dust and SO_2 removal.

2. *Circulating Liquor Treatment.* The determination of ways and means whereby,

(*a*) outside the scrubber—supersaturation of the circulating liquor with calcium sulphite and sulphate could be either completely or substantially destroyed;

(*b*) inside the scrubber—the scaling potential arising from slight supersaturation of the circulating liquor with calcium sulphite or calcium sulphate could be controlled and maintained below the higher limit, at which it cannot overcome the scaling resistance of the packing chosen.

3. *Plant Control.* The development of a pH recorder, operated from the power mains, having a degree of sensitivity consistent with close plant control, having a degree of reliability better than, or equal to, most of the instruments normally installed on boiler plants, and having technical characteristics not beyond the ready comprehension of the average boiler plant engineer.

The flue gases entering a scrubbing plant may contain:

Grit and dust	1.5 to 7 gr per cu ft at N. T. P.
CO_2	10 to 14 per cent by volume
O_2	9 to 4 per cent by volume
SO_2	0.05 to 0.20 per cent (or 0.3 to 1.1 gr sulphur per cu ft)
SO_3	traces, up to 10 per cent of weight of SO_2
HCl	traces, of the order of 0.05 gr HCl per cu ft
NO and NO_2	traces, of the order of 0.05 gr combined nitrogen per cu ft
N_2O	corresponding to partial pressures of 0.05 to 0.08 atmos.

To obtain complete, or substantially complete, absorption of the SO_2 and other acid gases with a closed recirculating water system, it is necessary to add on alkali. Lime or reactive powdered chalk are the cheapest alkalies, and are added in the form of a slurry. If lime is added to water used in washing flue gases, it rapidly combines with the CO_2 dissolved in the water to produce chalk, ($CaCO_3$), which is insoluble, and calcium bicarbonate, [$Ca(HCO_3)_2$], which is soluble.

Addition of chalk directly will also result in the formation of calcium bicarbonate. It is the dissolved calcium bicarbonate which is the active absorptive agent for the acid constituents in the flue gases. Fresh calcium bicarbonate is continuously formed from the chalk (whether chalk or lime is added), as absorption and neutralization of the acid constituents in the flue gases proceed.

When lime or reactive powdered chalk are added continuously to the circulating liquor at a rate equivalent to that of acid absorption, the pH of the liquor falls from a value between 6.5 and 6.8 at the liquor inlet to the scrubber to a value between 6.0 and 6.2 at the liquor exit.

The SO_2 and SO_3 are absorbed from the flue gases as calcium sulphite and calcium sulphate respectively, and since none of the recirculating water is put directly to drain, the liquor in the system is saturated with these relatively insoluble compounds. The two salts $CaSO_3 . 2H_2O$ and $CaSO_4 . 2H_2O$ (calcium sulphite dihydrate and calcium sulphate dihydrate (gypsum), respectively) are precipitated. The other reaction products, such as calcium chloride and calcium nitrite, are highly soluble, and owing to the slight water loss from the system (with the solids), and the resulting slight water make-up they do not reach saturation in the circulating liquor or solution. It should be noted here that the solubility of calcium sulphite increases with a fall in pH and that consequently the liquor leaving the scrubber can hold more of this salt in solution than that entering the scrubber.

Since, in solution, calcium sulphite is readily oxidized to calcium sulphate, a substantial part of the calcium sulphite produced in the plant is oxidized, partly in the scrubber, for the flue gases contain oxygen, and partly in the circulating system outside the scrubber. This oxidation is catalyzed by traces of iron and manganese salts. Both of these are present in the ash from the coal and in the lime added, and pass in part into solution in the circulating liquor. The nitrites present may also oxidize part of the calcium sulphite.

As a result of oxidation, the sulphur absorbed as SO_2 and SO_3 from the flue gas appears in the precipitated solids or mud of the circulating liquor as a mixture of calcium sulphite and sulphate (30 to 80 per cent of the total sulphur as $CaSO_4 . 2H_2O$, and 70 to 20 per cent as $CaSO_3 . 2H_2O$, according to the oxidizing and catalyzing agents present).

Water Makeup Relatively Small

The flue gases, in passing through the scrubber, come into thermal equilibrium with the circulating liquor, are cooled to their "wet bulb" temperature and leave the scrubber saturated with water vapor. Some loss of water thus results from the evaporation necessary to

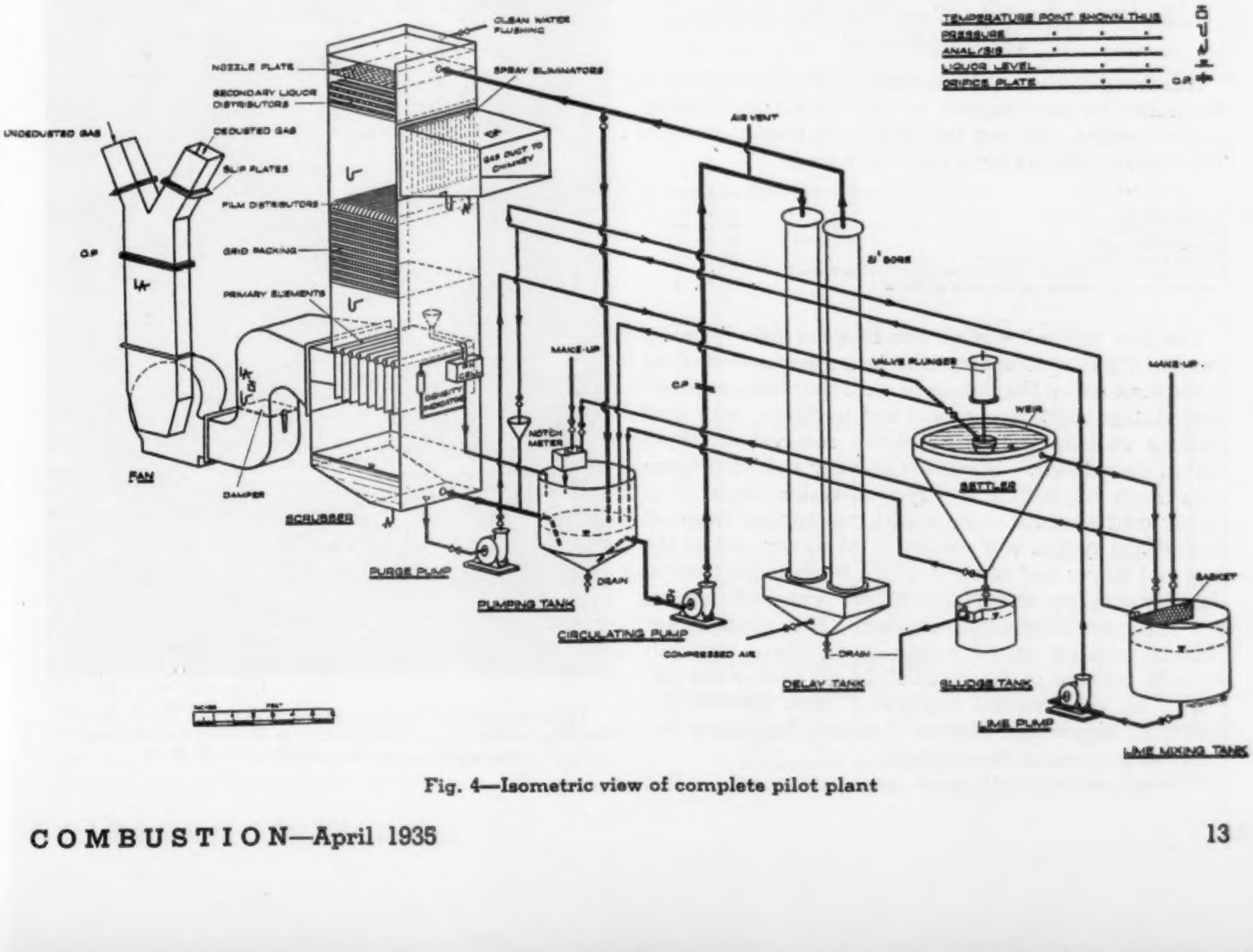


Fig. 4—Isometric view of complete pilot plant

effect such saturation. In addition, water is lost from the system through being entrained or chemically combined with the solids (ash, $CaSO_3.2H_2O$, $CaSO_4.2H_2O$) which are discarded after separation. The water make-up required to compensate for these losses is relatively small, and amounts to slightly over half a ton of water per ton of coal fired.

The final details of design and operation of a plant working on the lines generally indicated have been thoroughly delineated, explored and confirmed by continuous tests, extending over a period of 20 months, on a full scale experimental plant unit installed on a boiler plant.

Lime Preferable to Chalk

On technical grounds, it is preferable to add the alkali as lime rather than chalk because:

(*a*) Lime is the more reactive and uniform;

(*b*) The change in pH in the cycle is greater with lime, with some consequent beneficial effect on closeness and ease of plant control;

(*c*) The greater change in pH enables a smaller scrubber to be used for flue gases resulting from burning the higher sulphur coals.

In order to avoid corrosion of the scrubber hopper, it is necessary to keep the minimum pH of the liquor above 6.0. Hence the chalk used must be finely ground and fairly reactive if it is to be rapidly dissolved by the CO_2 in solution, and if no great excess is to be used.

The pilot plant was in continuous operation from April 1933 until December 1934 (apart from a small fraction of this time, required for plant modifications). The general arrangement of the pilot plant, in its final stages of development, is shown in Fig. 4.

Test Results on Pilot Plant Show High Sulphur and Dust Removal

Numerous tests have been made on the pilot plant to determine its performance in the extraction of dust, sulphur oxides, nitrogen oxides and hydrogen chloride. The average efficiencies of removal were:

	Per cent removal
Sulphur oxides	97 to 99
Nitrogen oxides	60 to 70
Hydrochloric acid	90 to 93
Grit and dust from P. F. boiler	97 to 98
Dust from P. F. boiler left in flue gas after having passed through a well-known wetted tube deduster	90 to 93

The test performance of the Howden pilot plant is compared with systems installed in a number of stations in England and on the Continent. At Battersea, a stoker-fired station employing sprays and packings, with final alkaline washing tests have shown removal of 90 per cent of the sulphur. Plants in Germany and other countries which employ the dry cyclone system show 60 to 72 per cent removal of dust with no sulphur removal. The wetted system will remove 91 to 93 per cent of the dust and 20 per cent of the sulphur, whereas the electrostatic system has shown 75 to 98 per cent dust removal but does not handle the sulphur. The Modave wet washers installed at Vitry Station in Paris take out 90 to 95 per cent of the dust and 18 per cent of the sulphur. An experimental corrugated plate deduster installed at Brimsdown Station, England, has taken out about 70 per cent of the sulphur.

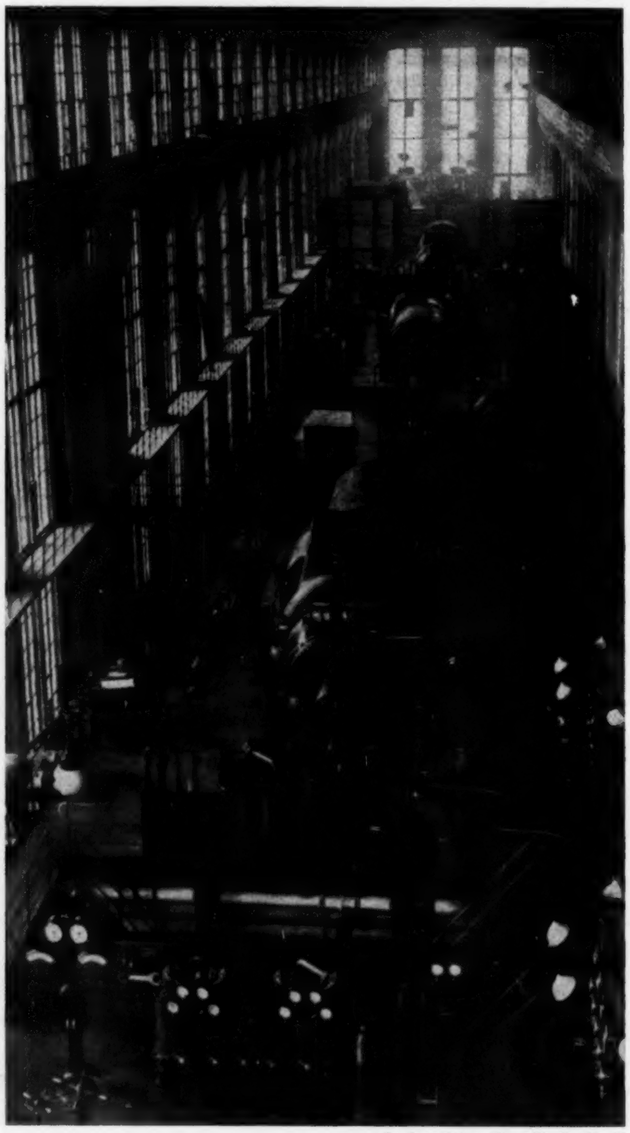
Index Campaign Underway

Dr. Frank B. Jewett, President of Bell Telephone Laboratories, Inc., and Vice President of American Telephone and Telegraph Company, has accepted the position of National Chairman of a campaign to raise a working capital fund of $161,000 for Engineering Index.

Announcement of Dr. Jewett's acceptance was made by Collins P. Bliss, Dean of the Engineering School of New York University, who has headed a movement to save the fifty year old index and annotating service of the engineering profession since it was discontinued as an activity of the American Society of Mechanical Engineers a year ago. The Index has now been incorporated as a non-profit corporation.

While the personnel of the National Committee is not yet complete it already includes a number of outstanding engineers who are actively promoting the campaign and its success seems assured.

Soviet Power Station



J. Jay Hirz, New York, N. Y.

Turbine room of Russian power station at Tcheliabinsk, Siberia. The installed capacity is 48,000 kw and much of the equipment was built in U. S. S. R.

The Derivation and Use of a Boiler Loading Schedule

By CHARLES F. TURNER
Chief Operating Engineer
Nebraska Power Co., Omaha, Neb.

Description of the method employed by the Nebraska Power Company in working up its schedule for loading boilers to obtain the best overall efficiency. This schedule is based on good average operating values, rather than test results, and is arranged in a convenient form so that it can be carried by each boiler room engineer.

THE question of boiler loading in a steam power plant, especially where there is a variety of sizes of boilers and variation in steam demand, has long been an interesting study. A great deal has been written on the subject and everyone seems to have a pet idea as to how the best loading can be accomplished. Many times an efficiency engineer will work out an ideal arrangement for a given condition or maybe for several conditions of steam demand, and then give the boiler room engineer specific instructions as to how the boilers shall be loaded on a certain day for a given load. This is all very well for the specific conditions, and he can run a test and get test results. However, we have made this question a sort of hobby and developed a plan whereby the boiler room engineer knows at all times just how to load each boiler for any given load in order to obtain the highest efficiency. He is responsible for results—not for a test, but for regular operation 24 hr per day.

In order to develop such a schedule, it is necessary first to determine boiler efficiency for each boiler at various loads. Having obtained this data, we plot the values for each boiler on a separate sheet as in Fig. 1, using evaporation in thousands of pounds per hour as the abscissa. In our own case this gives five distinct curves since we have five main operating boilers varying in size and design, and having variations in capacity from 110,000 to 250,000 lb per hr.

Our next step is to draw curves below each efficiency curve, showing steam temperature leaving the boiler. It may be observed that for these values we believe it best to use good average operating values rather than test results when the boiler and all heating surfaces are perfectly clean. In other words, it is well to give the operators a chance to obtain results approaching the bogey.

We are now ready to develop an "Equivalent Efficiency" curve for each boiler. This is done by taking the actual efficiency curve for any load and making a plus or minus allowance for change in turbine heat consumption rate due to change in steam temperature. For example, we use 690 F as a base and allow 1 per cent per $12^1/_2$ deg of temperature change. We now have in Fig. 1, the complete data on one boiler.

Every central station engineer knows within a few pounds how much coal is required for banking a boiler and thus can readily determine banking loss. Taking this loss into account, we now draw up a set of curves as in Fig. 2, which we call the "Combined Efficiencies" for various combinations of boiler arrangements. These curves are all very well for the efficiency engineer to ponder over, but they are of very little value to the man who is actually doing the work. Therefore, we have gone one step further and made up a tabulation showing how much steam should be obtained from each boiler to produce a given total steam requirement. In order to show how this tabulation is derived, a specific example will be given.

Assume the steam demand is 500,000 lb per hr and that we have all five boilers on the line, what loading will give the best efficiency? From the individual efficiency curves, we make an estimate at a series of loads; say, 50, 95, 95, 115 and 145 thousand pounds per hour on boilers Nos. 20, 21, 22, 23 and 24, respectively. Now, multiplying each output by its equivalent efficiency and dividing the sum of their products by the total steam demand, we obtain an "Overall Equivalent Efficiency" of 84.08 per cent. Proceeding in the same manner with various combinations we obtain the results shown in Table I.

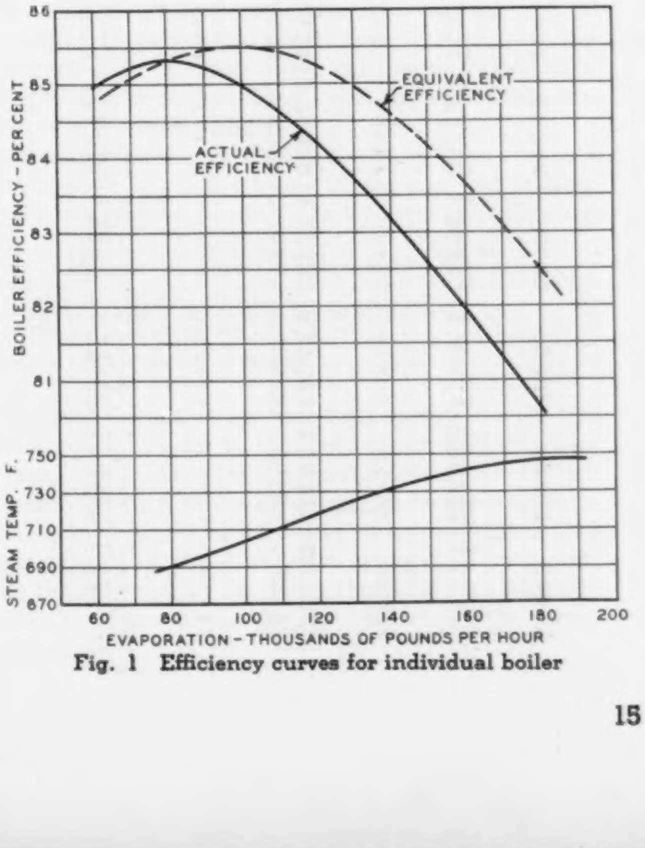


Fig. 1 Efficiency curves for individual boiler

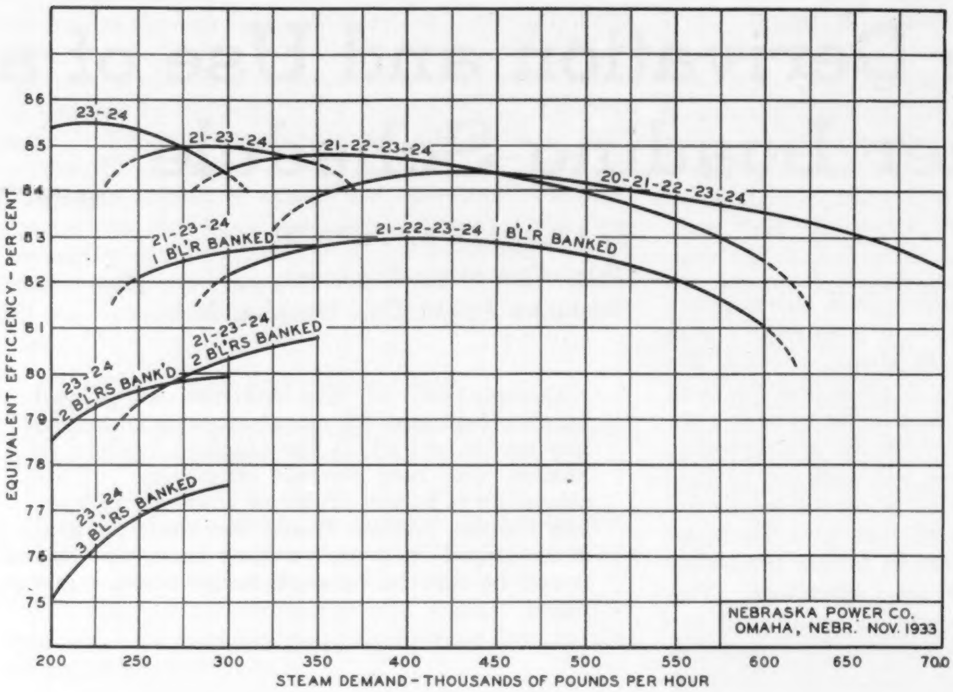


Fig. 2 Combined efficiencies for various boiler combinations

Equivalent efficiencies equal actual or calculated efficiencies plus or minus the correction for change in station economy due to change in superheat. Banking charge equals 800 lb per boiler per hour.

From the above six combinations, it is quickly seen that the most efficient combination is the 60- 90- 90- 115- and 145 thousand pounds per hour arrangement which gives a "Weighted Equivalent Efficiency" of 84.16 per cent. This 84.16 is derived by dividing the sum of the products (42,080) by steam demand (500) which gives weighted average.

Proceeding in increments of 25,000 lb, the best combination is attained. For combinations involving one or more banked boilers, the same procedure is followed with deductions made for the banked units. The result is that it is invariably more economical to keep as few banked boilers as possible.

Table II is a copy of the operating schedule as given to each boiler room engineer. By making this schedule in convenient form, it may be pasted on a stiff back and carried in his pocket, thus making it always available.

There is usually more possibility of saving real money in the boiler room than in any other part of the plant and therefore one should give the engineer all the help possible by giving him some definite information for ready reference. He will do the rest.

TABLE I—METHOD OF OBTAINING BEST OVERALL EQUIVALENT EFFICIENCY

Boiler Number	Thousands Lb Hour		Equiv. Effys.		
20	50	×	82.20	=	4,110
21	95	×	83.10	=	7,890
22	95	×	83.10	=	7,890
23	115	×	85.35	=	9,810
24	145	×	85.05	=	12,340
	500		84.08		42,040
20	70	×	82.50	=	5,770
21	90	×	83.25	=	7,490
22	90	×	83.25	=	7,490
23	115	×	85.35	=	9,810
24	135	×	85.30	=	11,510
	500		84.14		42,070
20	60	×	82.45	=	4,950
21	85	×	83.30	=	7,080
22	85	×	83.30	=	7,080
23	115	×	85.35	=	9,810
24	115	×	84.70	=	13,110
	500		84.06		42,030
20	60	×	82.45	=	4,950
21	90	×	83.25	=	7,490
22	90	×	83.25	=	7,490
23	115	×	85.35	=	9,810
24	145	×	85.05	=	12,340
	500		84.16		42,080
20	80	×	82.35	=	6,590
21	85	×	83.30	=	7,080
22	85	×	83.30	=	7,080
23	115	×	85.35	=	9,810
24	135	×	85.30	=	11,510
	500		84.14		42,070
20	60	×	82.45	=	4,950
21	75	×	83.35	=	6,250
22	75	×	83.35	=	6,250
23	135	×	84.80	=	11,400
24	115	×	84.70	=	13,110
	500		84.00		42,000

TABLE II—OPERATING SCHEDULE

Steam Flow M Lb Hr	Boiler Number 24	23	22	21	20
220	110	90			
225	125	100			
250	140	110			
275	150	125		—	
300	165	135			
250	100	100	50		
275	125	100	50		
300	125	100	75		
325	135	110	80		
350	145	120	85		
300	100	90	55	55	
325	115	100	55	55	
350	120	100	65	65	
375	125	105	70	70	
400	130	110	80	80	
425	140	115	85	85	
450	150	120	90	90	
475	160	125	95	95	
500	165	135	100	100	
525	170	135	110	110	
550	180	140	115	115	
575	185	150	120	120	
600	200	160	120	120	
350	100	90	55	55	50
375	115	100	55	55	50
400	120	100	65	65	50
425	125	110	70	70	50
450	135	105	80	80	50
475	145	115	80	80	55
500	145	115	90	90	60
525	150	125	90	90	70
550	155	125	95	95	80
575	160	130	100	100	85
600	165	135	105	105	90
625	170	135	110	110	100
650	180	140	115	115	100
675	190	155	115	115	100
700	200	160	120	120	100
725	215	170	120	120	100
750	225	180	120	125	100
775	235	185	125	130	100
800	245	190	125	130	110

It costs us 800 lb coal per hour to bank a boiler. Therefore, as many boilers as possible should be kept on the line at all times unless it is intended to let a boiler out entirely. In other words, the fewer the banking hours the better.

Firing Studies in an Institutional Power Plant

By E. G. ROBERTS
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An accounting of power plant records and costs setting out a future policy of base load operation with coal and peak load operation with gas firing in an institutional plant operating with two stoker-fired and two gas-fired boilers and two hand-fired boilers in reserve.

WHEN mapping out future plans of operation for a power plant calculations are sometimes based on selected or isolated data from the plant records. The engineer may pick out an evaporation which is representative for the type of firing employed, and the remaining data used may be based on desirable figures that do not appear sufficiently often on his plant records. This form of investigation is likely to give anticipated results that are far above the particular plant's usual level. Sometimes figures are taken from a summary of records of different plants throughout the country, but one can hardly expect to obtain a true picture of the plant's operation when using this procedure as there are sectional differences which are readily reflected in the cost of transportation, labor, maintenance and repair work. There is also the possibility of high repair and renewal costs because of the age of the equipment. These changing unit costs, which occur more frequently in the small and medium sized plant, are sufficient reason for a separate study of each plant based on its own particular conditions.

Private institutions and schools frequently allow their plants to stand off as neglected members of the building group, especially when a study of antiquated or obsolete equipment is carried out. Other than to carry on the operation from year to year without increases in the budget, very little attention is focussed on relative costs such as maintaining the steam-driven boiler feed pumps, a comparison of firing with stokers against hand firing, or the fluctuating costs of maintaining grates, walls and tubes on antiquated boilers. It is the engineer's responsible task to isolate these conditions of wasteful expenditure, and at the same time to recommend new policies which will serve to reduce materially the operating costs and consequently to reduce the financial outlay of the institution. He must gain the right to lay his findings before the authorities just as does an accountant.

It is the purpose of this article to present such a survey of firing in an institutional plant from detailed data obtained from the cost accounting and operating records of its recent years of operation. The object is to gain a true perspective of the plant's condition throughout, based on the past few years records averaged to cover an operating period of one year. This accounting covers two different types of firing, namely, underfeed stokers of the single-retort type, burning a southern bituminous coal, and natural gas firing with multiple burners.

In preparation for a survey of this nature, the following must be established: cost of handling and firing the coal and removing the ashes; average operating efficiencies for the two fuels; maintenance and power costs of the equipment utilized in conveying the water to the boiler, firing the fuels, and aiding in the transformation of water into steam; consistent analyses of the flue gases with the two fuels; and lastly, average daily steam load conditions for the year. In Table I, is listed the coal analyses, the air and products of combustion for the given consistent value of excess air, also the Orsat analysis and calorific value of the coal.

Table II gives the corresponding physical data for the natural gas. Table III gives the heat balance for the two fuels, in per cent. Table IV gives the special data from averaging the yearly records and from plotting the steam load conditions from the load curve shown. Table V gives the yearly records of the costs of producing steam in this plant for four years, representing the lowest yearly cost figures of fuel firing over a period of fifteen years.

With this essential summary of facts to work with, it is with the greatest of assurance that one can project the costs of operation into the future. The future policy to be studied on the basis of the existing records is base-load operation with coal firing, with the peak loads carried by the gas-fired boilers.

It is first necessary to find the cost of firing the fuels at the furnace door. Starting with the coal and tabulating all costs relative to this work we have the following:

Coal per ton cost, cars to destination	$4.18	
Cost per ton dry basis (coal weighed by carriers contains 4 per cent moisture)		$4.35
Cost of unloading cars, labor per ton		0.05
Cost of maintenance of pumps, stokers, boilers and conveyors		0.126
Cost of labor for firing, rolling and ash removal		0.562
Total cost of coal per ton fired at furnace		$5.088

To obtain the set-up for base-load operation with coal it is necessary to refer to the daily steam load chart for the year, here shown. On this chart a line is drawn which represents the total steam load that can be produced continuously by two 250-hp bent-tube three-pass stoker-fired boilers, operating at a continuous rating of 175 per cent. Under these conditions the coal will produce continuously 726,000 lb of steam per day, or 166,508,000 lb during the school year.

TABLE I. FIRING WITH A SOUTHERN BITUMINOUS COAL ORSAT READINGS AND CALORIFIC VALUES REPRESENT CONSISTENT AVERAGES OF TESTS TAKEN OVER APPROXIMATELY FIFTEEN MONTHS

Orsat Analysis		Ultimate Analysis	
CO_2	13.1%	S	2.3%
O_2	6.5	H_2	5.4
CO	0.5	C	71.3
N_2	79.9	N_2	1.7
		O_2	9.6
		Ash	9.7
	100.0%		100.0%
Btu (dry) as fired, 13,500		Btu (dry) 14,100	

Weight of air required and products of combustion

	Wgt. required for perfect combustion	Air required O_2	Air	Products of Combustion CO_2	O_2	N_2	H_2O	SO_2
C	0.713	1.901	8.220	2.619		6.310		
H_2	0.054	0.432	1.867			1.435	0.486	
N_2	0.017					0.017		
O_2	0.096				0.096			
S	0.023	0.023	0.099			0.086		0.046
Ash	0.097	2.356	10.186	2.619	0.096	7.838	0.486	0.046
O_2 as in gas		0.096	00.418		0.096	0.319		
SO_2 as CO_2				0.046				0.046
		2.260	9.771	2.665	0.000	7.519	0.486	0.000

The weight of air theoretically required for complete combustion is 9.771 lb per lb of coal. For each 10 per cent in excess of this amount, there will be added to the products of combustion:

$$0.9771 \times 0.2315 = 0.226 \text{ lb } O_2$$
$$0.9771 \times 0.7685 = 0.750 \text{ lb } N_2$$

Weights of products for excess air of 28.2 per cent

	100%	128.2%
CO_2	2.665	2.665
O_2	0.000	0.637
N_2	7.519	9.634
H_2O	0.486	0.486
	10.670	13.422

Weight of air required for the combustion of the coal equals 13.422 − 0.486 = 12.94 lb air per lb coal with 28.2% excess air.

The gas which will serve to take the peak loads, will produce 23,370,000 lb of steam for the year, taking the load above the base load line shown. Included in this amount will be the steam which must be produced by gas firing when the stoker-fired boilers are undergoing repairs, cleaning or inspection. Two days per boiler per month has been allowed for this routine on the basis of past experience. In the summer the two stoker-fired boilers will alternate on taking the load. Very seldom will the gas-fired boilers be required to take summer peaks or to take the full loads unless some emergency or breakdown occurs. From our past experience it has been found that one million pounds of steam is sufficient to allow for these irregularities as well as any others which may arise. One will notice that there is no banking of fires in this method outlined above. Should either of the two hand-fired boilers be used they will be fired up to their full rating, eliminating standby losses, and our only worry would be the average high evaporation which must be obtained.

TABLE II. BURNING NATURAL GAS ORSAT ANALYSIS AND CALORIFIC VALUE REPRESENTS THE CONSISTENT AVERAGE OF SERIES OF TESTS TAKEN OVER APPROXIMATELY FIFTEEN MONTHS TO TWO YEARS

Orsat Analysis		Ultimate Analysis	Volume	Weight, lb	Weight, %
CO_2	9.51%	Methane (CH_4)	0.906	.040800	0.8424
O_2	3.10	Ethane (C_2H_6)	0.042	.003280	0.0677
N_2	87.39	CO_2	0.006	.000741	0.0153
		Oxygen (O_2)	0.002	.000178	0.0036
	100.00%	Nitrogen (N_2)	0.044	.003440	0.0710
20.9% Excess Air.			1.000	.048439	1.0000

Air required for perfect combustion by weight

	Lb required for perfect combustion	Air required O_2	Air	Products of Combustion CO_2	O_2	H_2O	N_2
CH_4	0.8424	3.370	14.55	2.320		1.895	11.19
C_2H_6	0.0677	0.253	1.093	0.1985		0.129	0.840
CO_2	0.0153			0.0153			
O_2	0.0036				.0036		
N_2	0.0710						0.071
	1.0000	3.623	15.643	2.534	.0036	2.024	12.101
O_2 in Gas		0.004	0.016		.0036	0.012	
		3.619	15.627	2.534	.0000	2.012	12.101

The weight of air theoretically required for the complete combustion of one pound of gas is 15.627 lb. For each 10 per cent in excess of this one pound of gas, there will be added to the products of combustion:

$$1.5627 \times .2315 = 0.362 \text{ lb } O_2$$
$$1.5627 \times .7685 = 1.200 \text{ lb } N_2$$

Weights of products of combustion for excess air of 20.9 per cent

	100%	120%
CO_2	2.534	2.534
O_2	0.000	0.756
N_2	12.101	14.609
H_2O	2.012	2.012
	16.647	19.911

The weight of air required for the practical combustion of the gas with 20.9 per cent excess air will be: lb dry air per lb gas = 19.911 − 2.012 = 17.899 lb

Consistent average value of a cu ft of natural gas obtained from a series of tests is 1000 Btu.

TABLE III. HEAT BALANCE OF THE TWO DIFFERENT FUELS FOR THE MOST REPRESENTATIVE AVERAGE ANALYSIS OVER A LONG TIME PERIOD OF PRACTICAL COMBUSTION CONDITIONS

	Southern bituminous coal 28.2% excess air	Natural gas 20.9% excess air
	Per cent	Per cent
Heat absorbed by the boiler	73.20	69.00
Heat loss due to moisture in the fuel	0.17	0.00
Loss due to burning of hydrogen	4.54	12.05
Loss due to heat in the chimney gases	12.33	9.70
Loss due to moisture in the air	0.28	0.00
Loss due to incomplete combustion of carbon	1.86	0.00
Loss due to carbon in ash	2.29	0.00
Radiation and unaccounted for losses	5.20	9.26
	100.00	100.00

Coal Cost for Base-Load Operation

At the required steam pressure and temperature and with feedwater at 210 F it will take

$$\frac{1015 \times 1000}{0.732 \times 13,500} = 102.6 \text{ lb of coal per 1000 lb steam.}$$

The total cost of producing 1000 lb steam with coal will be

$$102.6 \times \frac{5.088}{2000} = \$0.261.$$

Gas Cost for Peak Load Firing

The unit cost per thousand cubic feet of natural gas will depend on the volume consumed. Maintenance and labor charges are far smaller than what has been found chargeable to the firing of coal in boilers, yet a charge is available. It will be easier to make allowances for these charges when figuring the gas fuel cost later in this paragraph. To develop 23,370,000 lb of steam by gas firing with an equivalent evaporation of 0.790, it will require 29,600,000 cu ft of natural gas with an industrial rate as given below. This amount of gas would cost:

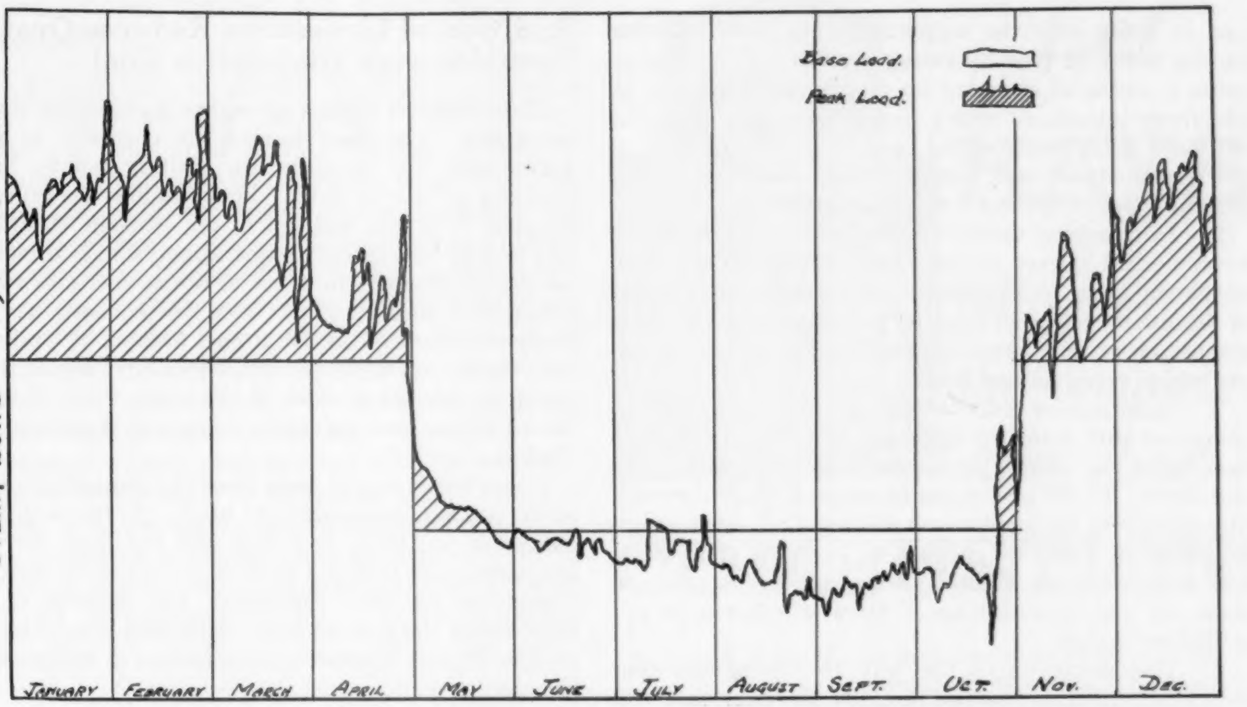
First	500 M cu ft	@ $0.31	—$155.00
Next	1000 M cu ft	@ 0.24	— 240.00
Next	1000 M cu ft	@ 0.21	— 210.00
Balance	27,100 M cu ft	@ 0.18	—4878.00
	29,600 M cu ft		$5483.00

The average cost of gas will be $\frac{5483}{29,600} = \$0.1852$ per 1000 cu ft at the meter. For the time of operation which will be far less than one year, the maintenance, power

TABLE IV. SPECIAL DATA

The values stated below are average values.

Feedwater temperature	210 F
Boiler room temperature	65 F
Exit flue gas temperature	625 F
Steam pressure (gage)	131.0 lb per sq in.
Steam produced by base load firing (under line on curve in Fig. 1)	166,508,000 lb
Steam produced by peak load firing (above curve line in Fig. 1)	23,370,000 lb
Total steam produced for the year	189,878,000 lb
Heat added to water per pound	1015 Btu



Typical average load curve (several years' record)

and labor costs for gas firing will amount to \$250.00. Adding this to the gas cost, the total costs will increase to \$5730.00. The average price of the gas per 1000 cu ft delivered to the furnace becomes:

$$\frac{5730.00}{29,600} = \$0.1935$$

With an operating efficiency of 69 per cent when burning gas and knowing that the boiler must supply 1015 Btu per pound of steam, we can readily obtain the number of cubic feet of gas required to generate 1000 lb of steam under these conditions:

$$\frac{1015 \times 1000}{1000 \times .690} = 1.471 \text{ M cu ft of gas per 1000 lb of steam.}$$

The total cost of producing 1000 lb of steam by natural gas burning at peak loads will be:

$$1.471 \times 0.1935 = \$0.2846$$

Base load operation by coal—peak load taken by gas:

$$\begin{aligned} \text{Coal—}166,508 \times 0.261 &= \$43,458.59 \\ \text{Gas — } 23,370 \times 0.2846 &= \$\ 6,631.10 \\ &\overline{\$50,089.69} \end{aligned}$$

If the reader will now refer to Table V, he will notice that at no time during the plant's operation has the yearly fuel and firing cost been this low. The records shown in Table V are for a composite firing of gas and coal; 20 to 50 per cent of the total steam produced was obtained from gas firing, and from 80 to 50 per cent from coal firing since 1932. Prior to this time all steam was produced by coal firing.

Recapitulation of Different Points in the Study

From a study of the heat balance, the engineer can diagnose the cause of his principal heat losses. This follow-up method of observation is familiar to all operating engineers as an invaluable method of locating and overcoming losses that are least expected. However, under the conditions of this study, any remedial changes will effect or improve average conditions over a long time period because it is to be remembered that all data has been averaged for periods of one year.

TABLE V. YEARLY RECORDS OF THE COSTS OF PRODUCING A QUANTITY OF STEAM IN THE SAME PLANT, THE TOTAL OF WHICH FOR EACH YEAR IS LESS THAN THE TOTAL GIVEN ABOVE, FOR FOUR YEARS REPRESENTING THE LOWEST FINANCIAL OUTLAY

Costs—Year:	1928–1929	1929–1930	1932–1933	1933–1934
Fuel.........	\$63,822.63	\$62,623.65	\$49,743.27	\$48,693.76
Labor........	7,342.00	7,152.00	6,024.00	6,213.00
Maintenance..	1,500.00	2,500.00	2,090.29	2,090.29
TOTAL......	\$72,664.63	\$72,275.65	\$57,857.56	\$56,997.05

From experience we have found the flue gas with natural gas firing will run somewhat lower in CO_2 due to the poor mixing of the gas and air with the abruptly changing load conditions. This fact will lower the results obtained to some extent, hence affect the costs because of the anticipated sharp load changes for the peaks. The increased cost, whatever it may amount to, will be absorbed by the higher efficiency of coal operation which is anticipated but was not used in the computation.

There has been a decrease in the maintenance costs of firing during the last two years. This fact is directly attributable to the rebuilding of the two stoker-fired units, which carried the major portion of the load during this period of operation. If an increased percentage of the load is given to the stoker-fired boilers, it stands to reason that a larger increment of reduced maintenance costs will be expected. The maintenance costs for the gas-fired boilers are not decreasing; if anything, they are increasing because no complete overhauling has been done on these two units. Again, a reduction of operating costs will further increase the savings under the future policy as outlined.

Summary and Conclusions

1. A comparison of maintenance, power and labor costs per ton of coal fired with 1000 cu ft of gas burned

can be made with the supporting data obtained after careful study of past operating records. From the results, a means of checking up on the operation can be effectively introduced with a view to increasing either the efficiency or the economy of operation. In the light of the results as obtained, future policies differing from the present types of operation may be instituted.

2. In a fashion similar to the auditing procedure in a commercial concern, we have here a method of approach which will serve to illuminate the respective advantages or disadvantages of all types of firing under any circumstances or at any location, whether the fuel be wood, pulverized coal, gas, anthracite coal or oil.

3. Maintenance costs of various items can readily be compared with standard figures, to obtain a rough comparison of the plant's unit operation costs with other standards. In the case of maintenance costs, too great a discrepancy in the comparison will serve to tell the engineer that it would be cheaper to buy new equipment. Likewise, too great a difference in unit labor costs will show too high a percentage of labor whether it be unskilled or skilled.

4. This study paves the way to finding the best policy of operation and incidentally the fuel that will bring about the best performance. Coal would not have proved to be the best fuel to use if standby and banking operations had been included for all coal firing, eliminating the gas firing in the meantime.

5. Lastly, because of the reduction of expenditures in the yearly operating budget to an amount far below the figure set out for this period, there will be funds returnable to the plant's credit. This can serve as a sinking fund from which sums may be drawn to purchase new equipment; to take care of carrying charges on new equipment; or to replace old equipment by following a definite plan of plant rehabilitation for the boiler and pump room.

Pulverizing Characteristics of Coal

The A.S.T.M. Subcommittee on Pulverizing Characteristics of Coal recently approved for presentation to the main committee two tentative methods of test for determination of grindability of coal. One of these methods is a ball-mill method developed at the Northwest Experiment Station of the U. S. Bureau of Mines, and the other is a method devised by R. M. Hardgrove which makes use of a specially designed machine. The latter has the advantage of speed in testing, whereas the ball-mill method requires a somewhat longer time but has the advantage of low cost of equipment.

These two methods were selected after a careful cooperative investigation of various methods whereby grindability tests were made by different laboratories on a series of five coals covering a wide range in hardness. Standardization of methods for determination of coal grindability is important in evaluating the pulverizing characteristics of various coals of the country and in checking the operation of mills used for the production of pulverized coal for boiler plants.

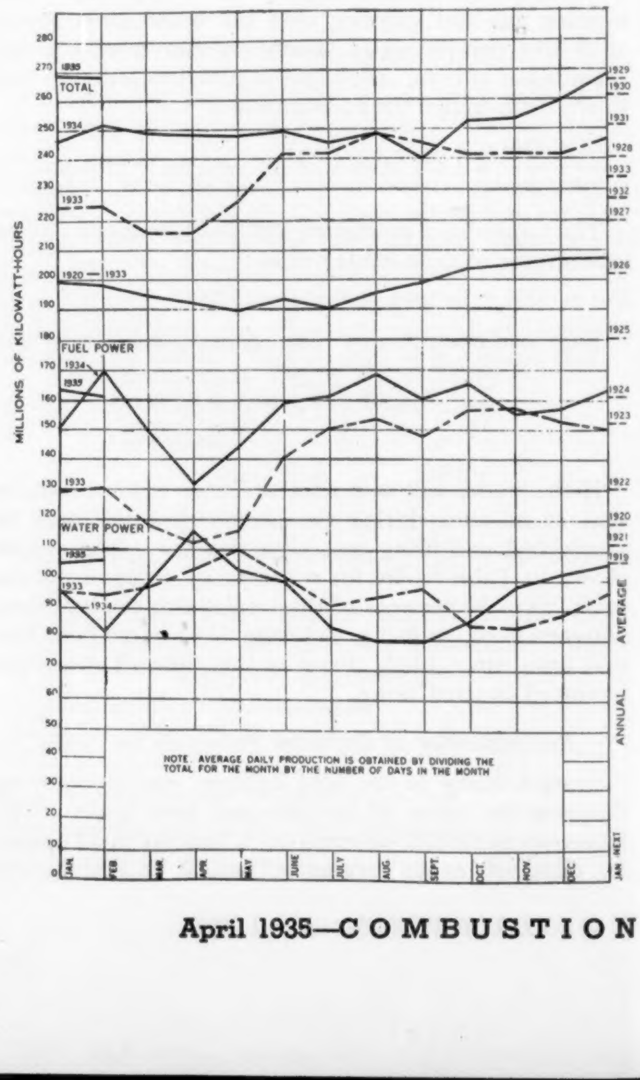
Addition of Limestone Reduces Grate Troubles with High Silica Coal

Many western coals have rather undesirable slagging properties. The slags formed are corrosive to stoker grates and, due to their low melting points, have a tendency to be very fluid. They run over the grates and interfere with the passage of air through the fuel, in addition to imbedding comparatively large amounts of unburned carbon. In order to devise methods for producing a suitable clinker from these coals, a careful study was made of the ash from a number of Utah coals. The results of these investigations are reported in a paper by Messrs. Cowles, Ravitz and Peck to be presented before the American Chemical Society at New York on April 26.

It was found that in most cases the proportion of silica in the ash was comparatively high. As the screen sizes increased, the silica increased and the lime decreased. Indications are that the high silica content of the coal is responsible for grate corrosion. The addition of limestone raised the melting point of the slag several hundred degrees, greatly decreased the corrosion of the grates and produced a porous satisfactory clinker.

Production of Electricity up to 1929

The following chart compiled by the U. S. Geological Survey, shows the total production of electricity for public use in the United States by months for several years past, also that generated by fuel and by water power. Averages for preceding years are indicated at the right.



Revised Rules Issued for Fuel Burning Equipment

The Department of Smoke Regulation, Hudson County, New Jersey, has just issued its revised rules covering the installation of fuel burning equipment. These apply to stationary power boilers, portable boilers, heating boilers, domestic warm air furnaces, incinerators and process furnaces. Rules for locomotives and marine equipment are to be issued later. The following are excerpts from the regulations pertaining to power boilers:

Each power boiler having more than 120 sq ft of heating surface shall be equipped with a mechanical underfeed or chain-grate stoker, apparatus to burn pulverized coal, oil burners or gas burners.

Chain-grate stokers shall have an ignition arch with a minimum length equal to three-fifths of the length of the active grate and such stokers shall be provided with overfire air with a minimum static pressure of 12 in. of water at the nozzle. Each such stoker, together with the number and location of the nozzles shall be approved.

If steam-air jets are used in an existing power boiler, there shall be one such jet for each 300 to 500 sq ft of heating surface or fraction thereof, and the minimum number of such jets shall be three. Their location and construction shall be approved by the Department.

Minimum furnace heights of power boilers equipped with mechanical stokers, to be operated at 150 per cent or less, are to be installed in accordance with minimum furnace heights as recommended by the Stoker Manufacturers Association. Where the boilers are to be operated at more than 150 per cent rating the furnace heights shall be subject to special ruling by the Department.

When pulverized coal is to be used the required combustion space for all power boilers having a maximum rating of 500 hp or less, and having refractory walls, shall be determined on the basis of a maximum heat liberation of 20,000 Btu per cu ft per hr. Where oil is used as fuel, the required combustion space for all power boilers having a maximum rating of 500 hp or less, and having refractory walls, shall be determined on the basis of a maximum heat liberation of 30,000 Btu per cu ft per hr. For larger boilers and other types of walls, with either pulverized coal or oil, complete details of design shall be submitted. An acceptable method of collecting fly ash from the stacks or breechings of all pulverized coal plants shall be provided.

All fuel burning plants shall be equipped with smoke indicators or similar devices approved by the Department of Smoke Regulation, to enable the operating crew to observe smoke conditions from the boiler room at all times. This provision shall apply to all existing boilers having more than 250 sq ft of heating surface, when new oil burners or mechanical stokers are installed.

Designs of stoker, oil burners and pulverized coal burning equipment shall be submitted to the Department for approval in all cases.

Copies of these revised rules may be obtained by addressing the Department of Smoke Regulation, Court House, Jersey City, N. J.

Nanking, China Extends its Power Facilities

The boiler plant of the 10,000-kw extension now being made to this Chinese central station consists mostly of American equipment in contrast with equipment of German make in the original section of the station. Steam is supplied by two steam generators, each rated at 100,000 lb per hr (132,240 lb maximum capacity), each served by two air-swept tube mills and corner fired by duplex tangential burners. A high ash, local coal is burned and, in order to care for both the present and anticipated load demands, the boiler plant was designed for a wide range in rating.

THE Capital Electricity Works, which serves the municipality of Nanking, China, has for some years operated with a steam station containing two 70,000-lb per hr cross-drum, sectional-header boilers of Borzig design, fired by Steinmuller (German) forced-draft, chain-grate stokers, and supplying steam to a 2500-kw turbine-generator. A steadily increasing industrial and domestic load, especially in the use of electrical appliances, made it necessary early in 1934 for the company to plan for an extension to the present station. These plans took into consideration not only the needs of the immediate future but anticipated the probable increase in load several years hence.

Accordingly, inquiries for equipment were submitted by the company to a number of European and American firms. All proposals were reviewed by a committee of seven appointed by the National Construction Council of China. With one or two exceptions, the boiler plant equipment finally selected was of American manufacture.

The conditions to be met involved a fairly steady load with occasional peaks. This load will be low in the immediate future, but to take care of anticipated growth two boiler units of 100,000 lb per hour continuous rating (with maximum efficiency at 80,000 lb per hour) were specified to supply 10,000-kw turbine capacity. A steam pressure for the present of approximately 400 lb was decided upon although the equipment was to be capable of operating at a somewhat higher pressure should future conditions so warrant. The Hwanan Coal burned at this plant has the following proximate analysis:

Moisture	9.27 per cent
Volatile	28.49 per cent
Fixed Carbon	43.49 per cent
Sulphur	0.96 per cent
Ash	18.75 per cent
Fusing temperature of ash 3002 F	

After considering proposals covering several types of boilers, with both stokers and with pulverized coal firing, the Committee finally decided upon two C-E steam generators, Kennedy-Van Saun air-swept tube mills and C-E tangential pulverized coal burners, of the duplex type, orders for which were placed through the Sintoon Overseas Trading Company last summer.

The high percentage of ash in the coal made it desirable to pay special attention to the fineness and uniformity of pulverizing, to the velocity of fuel and air and to the length of flame travel. Also, the high surface moisture and the necessity for insuring satisfactory combustion at light loads dictated the use of preheated air at approximately 400 F. On the other hand, high melting point of the ash permitted a simple ash-pit design.

The steam generators are designed for 525 lb per sq in. but will operate at 400 lb at the superheater outlet for the present and 725 F steam temperature. They may be operated at 470 lb in the future if desired. Each has 9542 sq ft of water heating surface of which approximately 80 per cent is in convection surface. There is also 2420 sq ft in the Elesco superheater located upon the furnace roof tubes. The C-E plate-type air heater, located immediately behind the drums and forming an integral part of each unit, has 25,700 sq ft. Plain tubes are used for the water walls and water screens. The upper drum is 48 in. diameter and the lower drum 42 in. diameter both being fusion welded. The entire unit, including the air heater, is enclosed in a steel casing over 2 in. of firebrick and 3 in. of rock wool.

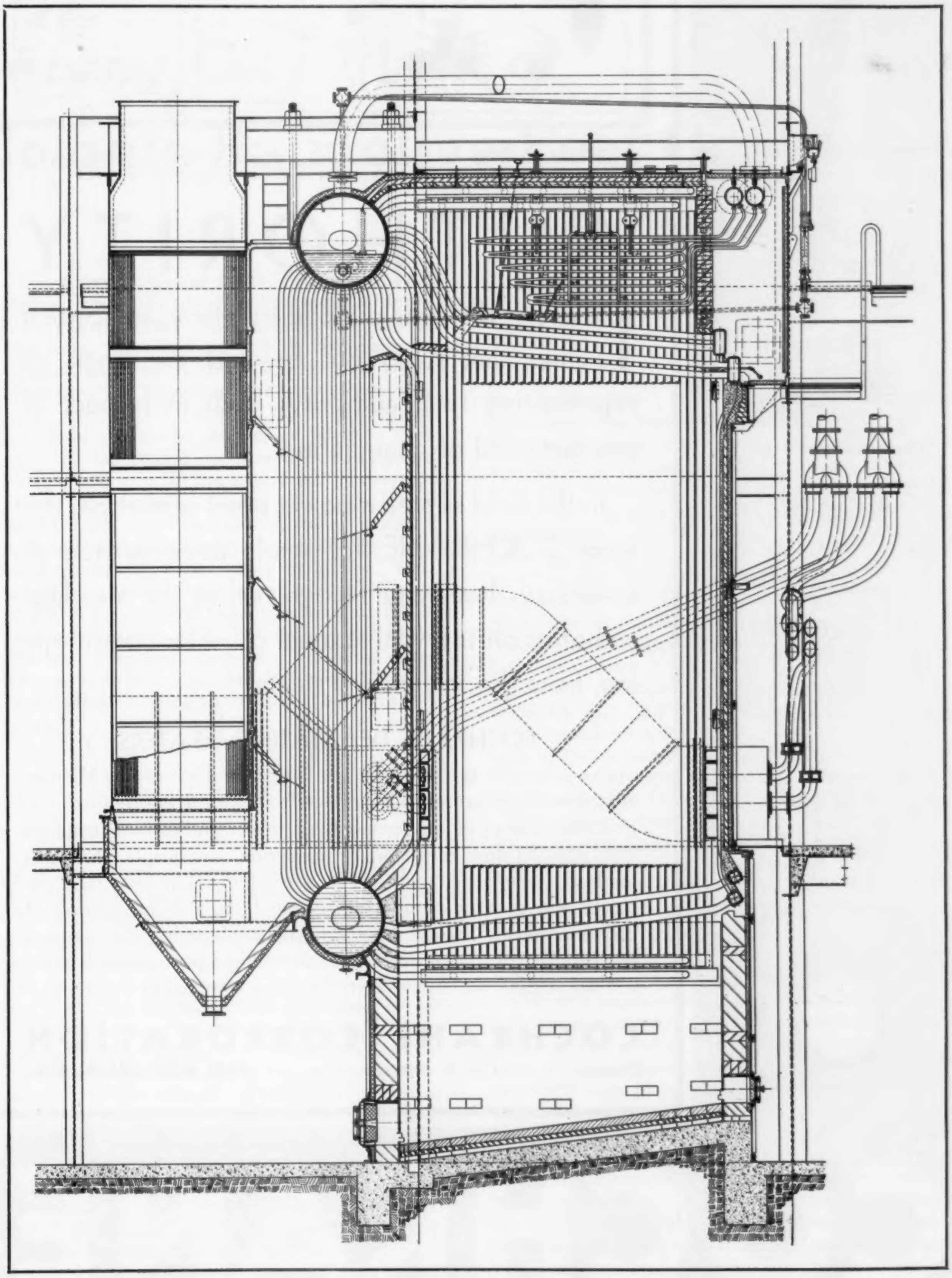
Each furnace is fired by eight tangential burners, two in each corner, and at guaranteed rating the calculated heat release will be around 30,000 Btu per cu ft.

Inasmuch as the load will at times be light, especially during the next year or two, the units were designed for a wide range in rating, namely, from 27,600 lb of steam per hour to a maximum for two hours of 132,240 lb of steam per hr. There are two mills per boiler and the fuel piping is so arranged that each mill supplies four burners, one in each corner; that is, one mill supplies the upper burners and the other the lower burners. Hence at light loads only one mill will be in use.

Provision is made for tube cleaning by the installation of six Bayer soot blower elements per generator. Four of these are mounted so as to blow the water walls comprising the combustion chamber and the remaining two will clean the horizontal and vertical banks of convection tubes respectively.

Among the boiler accessories of American manufacture selected are Copes feedwater regulators, Reliance gauge columns, Crosby steam gages and Edward blow-off valves. Extension of the existing coal handling system is being furnished by the Jeffrey Manufacturing Company. The forced- and induced-draft fans, it is understood, have been ordered abroad.

The steam generators were shipped from this country late in December and are now being erected.



Cross-section through one of two steam generators now being installed at Nanking, China

Power Developments at the Jersey City Plant of Colgate-Palmolive-Peet Co.*

By GOSTA ANBRO

Power Engineer
Colgate-Palmolive-Peet Co.

An account of the growth in power and steam demands during the past thirty-nine years. Until now steam for power has been supplied at 145 lb pressure to Corliss engines exhausting at 5 lb back pressure, for heating and some process, and the major portion of the process has been supplied direct at 90 lb. Two new 60,000–80,000 lb per hr bent-tube boilers are now being installed to operate at 448 lb pressure. These will burn No. 4 buckwheat on travelling-grate stokers and will supply steam to a 1000-kw turbine-generator exhausting at 95 lb. Two smaller units are also being installed, one of 250 kw capacity taking steam at 90 lb and exhausting at 5 lb and the other of 350 kw to operate between 4 lb and condenser vacuum. A third boiler and a second 1000 to 1500-kw turbine will be installed later.

WHEN electric power was introduced at the Colgate plant in Jersey City about 1896, an error in arithmetic was destined to have far-reaching consequences. A 25-cycle, belt-driven generator was installed and in figuring the pulley diameter, somebody slipped up exactly 10 per cent. The result was a frequency of $27^1/_2$ cycles which is still standard for about two-thirds of the plant's power consumption.

It is difficult to conceive that the mistake could have gone unnoticed very long, but I can readily picture the reasons for not correcting it. Production foremen were probably enthusiastic over the output of their machines and no difficulties were experienced on account of the higher speed. Under those circumstances, to suggest a change which would decrease production capacity would be nothing short of sacrilegious. Thus, a power system of $27^1/_2$ cycles, 2-phase, 220 volts and four-wire distribution kept growing until 1928.

At that time a new process for soap powder called for additional power in excess of the plant's generating capacity. In order to get the process in operation without delay it was decided to purchase power from the Public Service company. In this connection we considered upon converting the purchased energy to parallel our own. With a direct-connected motor-generator set the least number of poles that would change the frequency exactly was 48 on the 60-cycle and 22 on the $27^1/_2$-cycle end at 150 rpm. This would have been a bulky and expensive machine. A 22- and 10-pole machine would make the change from 60 to $27^1/_4$ cycles and would have meant a scant 1 per cent slower motor speeds throughout the plant but even 1 per cent was enough to raise objections from production departments.

Some of the company's executives did not look with favor on the idea of investing more money in $27^1/_2$-cycle equipment. In the years since the first generator installation they had witnessed how the old controversy of 25 versus 60 cycles and 2-phase versus 3-phase had been settled in favor of 60 cycles, 3 phase. We all realized the advantages of adhering to a common, nationwide standard and it was finally decided to introduce a second power system in the plant of 60 cycles, 3-phase, 440 volts, distributed over three wires. At the same time it was decided to run the new distribution lines so that the majority of future motor installations could be 60-cycle, 3-phase. Since 1928 the 3-phase system has grown to over 1000 hp installed motor capacity and 135 kw installed lighting.

Naturally the question of generating the 3-phase power at our own plant came up for consideration. The soap industry is inherently well suited for generating its own power as a by-product from its steam requirements. The ratio of steam consumption to power consumption is anywhere from 50 to 250 lb of steam per kilowatt-hour depending on production methods, kinds of products and climatic conditions. The average is about 150 lb of steam per kilowatt hour.

The old prime movers, which are Corliss engines, take steam at 145 lb and exhaust at 5 lb gage. Originally all the exhaust steam was used for process work and feedwater heating. But 1928 changes in production methods had already decreased the demand for 5-lb steam so that a considerable quantity was wasted in the summer. During winter this excess was taken up for building heating.

The major portion of process steam is used at 90 lb pressure. The feasibility of operating a steam turbine

* A paper before the Metropolitan Section A.S.M.E., New York, Mar. 27, 1935.

against this back-pressure had been thoroughly established at other plants but the highest admission pressure we could get with the old boilers was 145 lb. This expansion range was too small for getting a worthwhile quantity of power from the process steam. High-pressure boilers were needed. An economic study showed that it would not be a very attractive investment to install high-pressure boilers solely for the purpose of power generation. Even the added incentive of higher efficiency for new boiler units was insufficient to make it a satisfactory investment, especially during the early depression years. It was decided to hold off the installation of high-pressure boilers and extension of the power plant until some of the old boilers had to be replaced due to age.

The question of when an old boiler has to be replaced is controversial but in our case it was settled when the insurance company advised us to cut down the pressure within a year. We received this notice last summer and started at once to work out plans for the installation of new boilers and a new power plant to take the load now carried by purchased power. These plans were approved in September of last year, together with a plan for changing all $27^1/_2$-cycle, 2-phase equipment to 60-cycle, 3-phase within a period of approximately five years.

The question of fuel for the new boilers was settled in favor of anthracite. This is decidedly the most economical fuel in our location under the present price schedules. It has also shown less price fluctuations than oil and bituminous coal during the last 8 or 10 years. It is possible and perhaps probable that No. 3 buckwheat, the size of anthracite commonly used in power plants, will be scarce in the future. To guard against this we decided to be prepared to burn the No. 4 size which we feel will be available at a reasonable price for many years to come.

Once the choice of fuel was made, the problem of fuel burning equipment practically settled itself. The traveling grate stoker has a practical monopoly on burning anthracite in power plants. Its efficiency with No. 3 buckwheat comes close to efficiencies obtained in bituminous coal plants. With No. 4 buckwheat the efficiency has in some cases been deplorably low but the requirements for success have now been fairly definitely established. The principal requirement is large grate surface to hold down the burning rate to 25 or 30 lb per square foot per hour.

What pressure to carry on our new boilers had been decided about a year earlier in connection with a new installation at our Jeffersonville, Indiana, plant. We decided there on 425 lb. This pressure gives ample possibilities for by-product power generation. Still it is not so high as to present any serious problem in feedwater treatment or other phases of operation. At Jersey City we stepped up the pressure to the maximum allowed for No. 8 gage, $3^1/_4$-inch boiler tubes, which is 448 lb. This gives us some additional available power which is desirable in view of the fact that the main office of the organization is located at this plant and adds considerably to the regular production load.

The steam temperature was set at 600 F or slightly below. With this initial temperature exhaust steam at 90 lb pressure will have 50 to 75 deg superheat. We consider this advantageous particularly in view of the fact that this steam, besides its principal use for process work is also used in numerous small steam drives around the plant.

With a steam pressure of over 400 lb some form of heat recovery equipment becomes an attractive investment. We finally decided on an economizer. The considerations preceding this decision were quite complicated, involving space and cost, juggling different types of boilers and duct arrangements, different ratios of the heat absorbed in the recovery apparatus to the heat absorbed in the boiler, the effect of preheated air on stoker maintenance, etc.

Space conditions had a lot to do with the design and arrangement of equipment. We had a vacant space in the old boiler room where one new boiler could be installed before tearing out any of the old boilers. Since the building, coal bunker and chimneys are in good condition we decided to install the new boilers in the old boiler room even though the arrangement of building and bunker imposed severe restrictions in two directions: height and front to rear. Unfortunately, we have not had time yet to make a complete arrangement drawing suitable for reproduction. Without this drawing it is impossible to explain in detail the arrangement of equipment and the reasons for it. I will state simply that we are installing a four drum bent tube type of boiler, with an economizer in back of it. The boiler will be cross baffled and the gas flow will be up through the economizer. This arrangement permits more effective settling of fly ash.

The question of natural versus induced draft was hard to settle. We have two brick stacks 275 ft high and maintained in good condition. It seemed odd to use induced draft in connection with these stacks. A low draft loss boiler and economizer could be made as efficient as a high draft loss installation by increasing the heating surface. The cost of this additional heating surface would only slightly exceed the cost of an induced-draft fan. It would be desirable to avoid the fan from the viewpoint of maintenance, reliability and power usage. Induced draft, on the other hand, could more easily be arranged to provide draft for overload conditions and fitted better into the available space. The overload possibilities with induced draft finally clinched the decision.

The capacity of the new boiler units was chosen equal to about one-third of our total load so that the plant may ultimately consist of four boilers of which one would then be a spare. Installation of two of these boilers is now in progress.

The heating surface of each boiler is 7700 sq ft and of the economizer about 3000 sq ft. Generating 60,000 lb of steam per hour, the flue gas temperature will be about 400 F and at 80,000 lb per hour about 450 F. The grate area is 287 sq ft which is considered sufficient for generating 60,000 lb of steam per hour with No. 4 and 80,000 lb per hour with No. 3 buckwheat without undue carbon loss.

The furnace will be of the rear arch design with front and side walls of tile supported from outside steel. This construction was chosen principally because any small section can be renewed without disturbing surrounding sections.

Water cooled walls and arch were not considered justified in view of the long life of plain refractories in anthracite burning furnaces. Also the amount of water cooling that can be introduced without courting ignition troubles is limited.

The new electric generating equipment had to be housed in a new building erected on a vacant lot adjacent to the boiler room. Due to the high value of ground in our location, this turbine room is designed to support a later superstructure of 6 stories with a floor load of 250 lb per sq ft. For this reason its interior appearance will differ from the general run of turbine rooms. Instead of a wide open space there will be heavy columns interspersed between the generating units.

One main generator of 1,000 kw capacity is now being installed. A second main unit of from 1,000 to 1,500 kw capacity will be installed later during the five-year program. The first unit is to take steam at 420 lb and exhaust against 95 lb. The second unit will have the same admission pressure but will exhaust against 5 lb and will probably have a bleeder connection at the 95 lb stage. The reasons for this uncertainty about the second unit are some new developments in process work.

At this point it is of interest to note that the maximum capacity of the new boilers is such that one boiler is sufficient to supply steam to the above main generating units in case the other boiler is down for repairs. Ordinarily, when two boilers are in operation, excess steam from the 420-lb main will spill over through desuperheaters and reducing valves into the 150- and 95-lb steam mains.

In addition to the 1000-kw unit we are installing two smaller ones. The purpose of these is threefold: 1, to control supply and consumption of 5 lb exhaust steam; 2, to take care of week-end loads; and 3, to provide spare generating capacity. These smaller units will be geared, while the main unit is direct-connected. One of the smaller units is a 250-kw machine taking steam at 90 lb and exhausting against 5 lb. The other unit is a 350-kw machine taking steam at 4 lb and exhausting to a condenser. The sizes of these units were chosen so that the exhaust from the back pressure machine is equal to the steam demand of the condensing unit at proportional load. In other words, the two can be operated as one unit without affecting the situation of 5 lb exhaust steam.

Whether to install two separate units or one condensing bleeder turbine was the subject of much discussion. The cost of either is about the same. Finally, the majority opinion was that the two-unit installation would have the following advantages over the single unit: 1, in the winter, when 5 lb steam is needed, it will not be necessary to start the condensing equipment; 2, in the summer when it is desired to use up 5-lb steam there will be a gain in efficiency equivalent to the windage loss in the 90- to 5-lb stages of a single unit; 3, a smaller unit is preferable for week-end loads; and 4, with the two units it was easier to arrange so that some power can be generated under most any condition of repairs that have to be made on steam mains.

Building an industrial power plant is a gamble on future trend in steam consumption. Process developments already in sight make it uncertain. Unforeseen developments are likely to change it in years to come as they have in the past. We have tried to provide equipment which will eliminate exhaust steam waste under present conditions as well as avoid it under possible changed conditions in the future. However, if somebody should call our estimate of the future a guess, we will gladly concede the point. We only hope that it does not turn out to be a poor guess.

A Wooden Boiler

Incredible as it may seem a wooden steam boiler was actually built and installed in the Center Square Pumping Station in Philadelphia in 1801. A model of this boiler now forms a part of the power equipment exhibit in the National Museum at Washington and is described in the current issue of *Mechanical Engineering*. Obviously it was an internally-fired boiler with a wrought-iron firebox and flue, but the steam and water space was enclosed by wood which it was believed would act as an insulator. The difficulty of keeping the boiler steam-tight soon became evident and it was replaced after a few years.

New York City to Study Atmospheric Pollution

A six months' day-by-day study of the atmospheric conditions in each of the five boroughs of New York City is to be made by the Emergency Relief Bureau under the direction of the Health Department. It is contemplated to employ about 190 engineers and observers, for checking conditions in various parts of the city, instructing firemen and in making laboratory analyses of samples of dust, dirt, fumes, etc., which contaminate the atmosphere. The plan is similar to that carried on about a year ago in Chicago.

C. B. Nolte Becomes President of Crane Co.

C. B. Nolte was elected president of Crane Co. on March 26, succeeding J. B. Berryman, who becomes Chairman of the Board.

Shortly after graduating in mechanical engineering from the University of Illinois in 1909, Mr. Nolte joined the Robert W. Hunt Co., consulting, testing, and inspecting engineers, and successively became division manager, manager, vice president and general manager, until in 1930, when he was appointed president and general manager. This position he held until he was elected to his present office.

Marion Penn, has been advanced from general superintendent of generation to general manager of the electrical department of the Public Service Electric & Gas Company of New Jersey, succeeding J. T. Barron, who becomes vice president. Mr. Penn has been with the company since 1914 and before being made superintendent of generation had served successively as chief engineer of the Essex and the Marion Stations.

R. T. Dinwiddle has resigned as Manager, Refractories Division of The M. W. Kellogg Co., to become vice president of Refractory & Engineering Corporation, New York City. In this new position, Mr. Dinwiddie will be in charge of sales of the company's complete lines of refractory cements and insulations.

The Enthalpy of a Working Substance

The author explains the meaning of the term "enthalpy" as the sum of the internal energy and the product of the pressure and specific volume, expressed in the same units. Diagrams representing the state surface of steam and the enthalpy surface of steam are included and discussed.

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AMONG the more important properties of a heat engine's working substance is a thermodynamic function commonly designated by the symbol h. This function h, for a given material, is defined as the sum of its internal energy (u) and the product of its pressure (p) and its specific volume (v); that is, $h = u + pv$. In engineering practice, it is customary to measure both the function h and the internal energy u in thermal units of energy per unit weight of working substance, the common unit being Btu per pound. To be consistent, the energy equivalent of the work represented by the product pv must also be expressed in the same energy units. When the pressure is measured in pounds per square foot and the specific volume in cubic feet per pound, the equivalent energy in Btu per pound is obtained by multiplying this product by the familiar constant, $A = \frac{1}{778}$, which is the reciprocal of Joule's Equivalent. Expressed in these units, then, this thermodynamic function is $h = u + Apv$.

The particular advantage of having a special symbol for $u + Apv$ is that this group of terms continually occurs in certain thermodynamic formulas such as those dealing with non-flow processes in which the pressure is constant and with steady-flow processes in which the pressure, although it may vary widely along the channel of flow, is substantially constant at given points along the channel. In practice, there are countless situations in which such equations are of practical use, since a great variety of apparatus in continuous service is operated either at constant pressure (boilers, condensers) or under steady-flow conditions (turbines, pumps, flow meters, etc.).

This function h has been given many names including this strange word *enthalpy* which has recently appeared in the literature of technical thermodynamics and which, apparently, is due to the late Dutch physicist, Kamerlingh Onnes.[1] The more familiar names are *total heat* and *heat content* and less well known are the names *thermal head* (Goodenough), *thermodynamic potential for given pressure* (Bryan), and *heat function for constant pressure* (Gibbs).

The common names, *total heat* and *heat content*, are unfortunate for h is not heat but simply $u + Apv$, the sum of the internal energy u and the energy equivalent of the work quantity pv. The word *content* is also misleading for it tends to confuse h with the internal energy u which is "contained" within the working substance. Such troublesome misconceptions arising from these unsound names for h largely account for the growing use of this new term *enthalpy*.[2]

The variation of this function $h = u + Apv$, as the state of the working substance is altered, will, of course, depend upon the properties of each particular material. In general, each of the variables u, p and v can be defined for any given state of the working substance. The values of p and v for any given state are absolute while the value of the internal energy u is purely relative since it must be referred to some standard state whose internal energy is arbitrarily assumed to be zero. It follows, then, that each point[3] on the state surface of the working substance has a corresponding value of the function h. These values of h, however, are relative inasmuch as u is relative and must, therefore, be referred to some standard state for which h is arbitrarily considered to be zero.

Steam, which is perhaps the most important working substance met with in practice, is characterized by the state surface[4] shown in the center of Fig. 1. This interesting diagram represents a plot of the p, v, T relations for steam. These data for conditions ranging from 32 F to 1000 F and pressures up to 3500 lb per sq in. absolute are given in Keenan's Steam Tables and Compressed Water Tables.[5] The data needed to extend the state surface from 32 F down to absolute zero, although as yet incomplete, are summarized in the International Critical Tables. The scales of this diagram have been modified to reveal clearly some of the more interesting details.

It will be observed that the wet steam conditions define a cylindrical surface perpendicular to the p-T plane and extending from absolute zero to the critical point where the specific volumes of saturated water and steam become equal. For steam, the coordinates of the critical point are p = 3226.0 lb per sq in. absolute, T = 706.1 F, and v = 0.0522 cu ft per lb. In a similar way, the p, v, T relations for mixtures of water and ice

[1] Faraday Society, 18:140.

[2] This new word enthalpy does have the advantage of being strange and, therefore, free from the misconceptions implied by the more familiar terms, but, when pronounced in the conventional way with the accent on the first syllable, it has the great disadvantage of being easily confused with the word entropy. To relieve this situation, it has been suggested that the accent be placed on the second syllable, but such pronunciation is awkward to many people. There seems to be a need for a new term that can win general approval as a name for the function h.

[3] At a triple point, an additional coordinate is required to specify the amount of each phase and thus fix the value of h.

[4] Described in *Power Plant Engineering*, April 1934.

[5] *Mechanical Engineering*, February 1931.

define another cylindrical surface perpendicular to the p-T plane. These two cylindrical surfaces intersect on the element AB of the wet steam surface and this line AB represents the "triple point" conditions. The triple point may be defined as the pressure and temperature at which the solid, liquid and gaseous phases of a substance may coexist in equilibrium. For steam this pressure is 0.0887 lb per sq in. absolute and the temperature is 32.0135 F, while the specific volume may range between A and B depending upon the amount of each phase present in the mixture. The remaining areas of the state surface of steam represent the various possible states of ice, water and superheated steam. It is interesting to notice that above the critical temperature the usual distinction between the liquid and gaseous phases no longer exists.

Each point on the state surface, except the triple point conditions AB, has a corresponding value of h. These values of h are relative since they must be referred to a standard state for which h is arbitrarily zero. In Keenan's Steam Tables, for instance, the zero of enthalpy is "arbitrarily placed on the saturated liquid line at 32 F." Strangely enough, this point does not represent a state of equilibrium and, consequently, it cannot be found on the state surface since this surface contains only equilibrium conditions. And further, of all the steam conditions listed in Keenan's tables, this one at 32 F is the only one that does not represent an equilibrium condition. The departure from equilibrium is, of course, small for the saturated liquid line ends at the triple point temperature of 32.0135 F so that the point of zero enthalpy is reached when water is undercooled only 0.0135 F. This state of zero enthalpy is shown as point C under the ice area of the state surface and again, more distinctly, as point C in the projection of this surface on the p-T plane. The scale in this region has been modified to display the situation clearly.

To illustrate visually these relative values of h for various steam conditions, a space diagram has been constructed using the projection of the state surface onto the p-T plane, shown to the left in Fig. 1, as a foundation from which the enthalpy values for a given point were laid off normal to that point. The result is the surface defined by the equilibrium values of the coordinates p, T and h, shown in Fig. 2. These scales are approximate only. If the pressure is maintained constant during the processes of vaporization, sublimation or melting (or their reverse), the temperature also remains constant so that the change in the value of h, under such conditions, defines the cylindrical surfaces labeled "water and steam," "ice and steam" and "water and ice." So long as there is only one phase present, there is but one value of h for each point on the p-T plane and these values describe the remaining areas of the enthalpy surface which are labeled "ice," "water" and "superheated steam." The triple point conditions again define the line AB, and the state used in the steam tables as the arbitrary zero for enthalpy is the point C, located just off the surface at 32 F on the extended saturated liquid line.

Keenan's Steam Tables and Compressed Water Tables cover the conditions above 32 F but below this temperature, the shape of the enthalpy surface is not so well known. From certain theoretical considerations, it would seem that the heat of fusion would decrease slightly as the pressure is increased, and that the heat of sublimation would fall away toward some finite value as the temperature is diminished.

A high-pressure Rankine cycle will serve to illustrate the need of enthalpy data within the range covered by the above tables. Referring to the state surface, suppose water at state 1 is compressed adiabatically (isentropically) to state 2, then heated at constant pressure until it is superheated steam at state 3, then expanded adiabatically (isentropically) to state 4 where it is condensed at constant pressure to water at state 1. Further, since this is an ideal cycle, it is permissible to assume that the elevation and the flow velocity are the same at these four points so that potential and kinetic energy terms cancel out. Each change of state can then be considered as a simple non-flow process. This cycle is described by the path 1-2-3-4-1 on the state surface

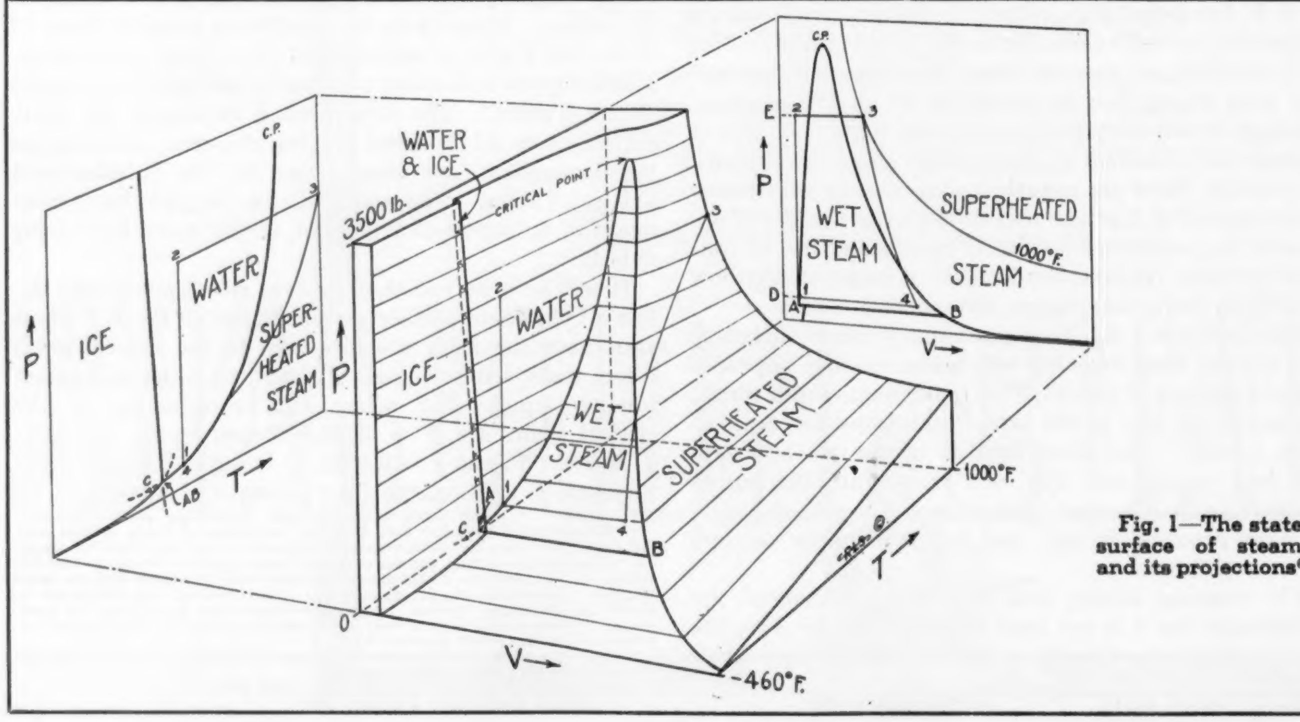

Fig. 1—The state surface of steam and its projections[6]

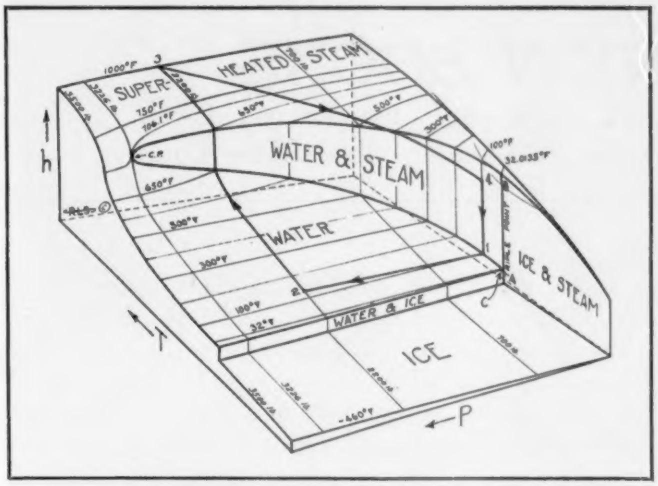

Fig. 2—The enthalpy surface of steam[6]

and also in the projections of this surface on the p-T and p-v planes. The projection on the p-v plane is of special interest for the area 1-2-3-4-1 in this diagram represents the net work done by the cycle.

It can be shown that the efficiency of such a cycle is given by the equation

$$E = \frac{(h_3 - h_4) - (h_2 - h_1)}{(h_3 - h_2)}$$

These enthalpy relations are clearly illustrated in the three-axis diagram shown in Fig. 2. The external *work* done on the water during adiabatic compression in the ideal feed pump is the enthalpy difference $(h_2 - h_1)$, represented by the difference in the elevation of these two points. In a similar way, the difference $(h_3 - h_2)$ represents the external *heat* transferred to the working substance at constant pressure in the boiler and superheater. The difference $(h_3 - h_4)$ is the external *work* done by the steam during the adiabatic expansion in the ideal engine. These are the differences which appear in the expression for the cycle efficiency. The difference $(h_4 - h_1)$, shown in Fig. 2, is the external *heat* transferred from the steam at constant pressure in the condenser.

In the course of the foregoing discussion, the properties of steam have been used to illustrate the principles involved—the choice of steam being prompted by the extensive use of this material as a working substance. The principles, however, hold in general for any substance be it hydrogen, ammonia, mercury, iron, etc. These materials have their own state surfaces and enthalpy surfaces which are, in most respects, quite similar to those for steam even though the numerical value of their data may differ greatly. It is interesting that at atmospheric temperatures and pressure, for example, the hydrogen ordinarily encountered in practice is a highly superheated gas; mercury, a liquid; and iron, a solid. Whatever the working substance may be, space diagrams, such as shown, aid greatly in giving a conception of the relationships which exist between volume, pressure and temperature and also such important thermodynamic quantities as this function h to which so many different names have been given.

REVIEW OF NEW BOOKS

Any of the books reviewed on this page may be secured from Combustion Publishing Company, Inc., 200 Madison Ave., New York

The A. S. H. V. E. Guide 1935

(13th Edition)

The 13th edition of this handbook of the American Society of Heating and Ventilating Engineers has just been published and copies are now available. *The Guide* is compiled annually by the Society for engineers and others interested in heating, ventilating and air conditioning, and it is planned as a practical, usable and authoritative reference book.

Though the Guide Publication Committee has produced a new book, it has retained from the older ones those data which are basic and fundamental, and it has made additions and changes to cover new developments in both theory and practice.

The Technical Data Section is a reference book and text, which in its 41 chapters covers the fields of heating, air conditioning, cooling, insulation and ventilation in their theoretical and practical aspects. Starting with factors fundamental to heating and air conditioning—air properties, air distribution, ventilation requirements, heat transmission coefficients of materials and of various structures—it carries on through discussions of the many types of heating, cooling and air conditioning needed, with their applications and methods of accomplishment. It describes systems of heating, cooling and air conditioning; fuels; apparatus and machinery; test methods and instruments.

A chapter on sound control considers the theory and practice of insulating against sound, and automatic control devices are fully covered. The machinery and instruments needed for the devices and systems discussed are described in detail. The concluding chapter gives abbreviations, values, symbols and conversion equations for the terms used in this text and related ones.

Wholly new this year, in addition to an inserted psychrometric chart, is the section called "Problems in Practice," which supplements Chapters 1 to 40, in the form of questions and answers relating to the material presented. These practical treatments summarize each chapter in an interesting and instructive way, and it is felt that this added feature will prove of great value to users of *The Guide.* A more comprehensive index to the Technical Data Section has been made in order that references may be more quickly checked in the text by the reader.

A major division of *The Guide 1935* is the Catalog Data Section of 224 pages, listing the products and services offered by leading manufacturers in the field, giving pictures, specifications and ratings. The Index to Modern Equipment, which follows, lists alphabetically by products the manufacturers who can supply the products named, with ready reference to the individual manufacturer's catalog data.

The Guide 1935 contains 1024 pages, size 6 × 9, bound in a flexible red cover. Price $5.00.

1934 A. S. T. M. Proceedings

The 1934 *Proceedings* of the American Society for Testing Materials are issued in two parts—Part I comprising the reports of the A.S.T.M. standing committees, together with all new and revised tentative specifications and tests; Part II, the technical papers.

Part I: In the section devoted to ferrous metals there are extensive reports on the following subjects: steel products; phosphorus and sulphur in steel; wrought iron; cast iron; corrosion; magnetic properties; ferro-alloys; iron-chromium-nickel and related alloys; effect of temperature.

Subjects in the non-ferrous metals field include corrosion in liquids and galvanic and electrolytic corrosion; electrical-heating and similar alloys; copper and copper alloys; die-cast metals and alloys (exposure and corrosion tests, with a paper discussing effect of aluminum content on the strength and permanence of No. XXIII zinc die-casting alloy); and, finally, the extensive report on service characteristics of the light metals and their alloys.

Also given are a proposed Diesel fuel oil classification, a suggested test method for agglutinating value of coal, a modified saponification test for insulating oils, and methods for testing the adhesion of rubber to metal. The use of the tension test for judging suitability of sheet metals for various purposes is discussed.

Some fifty specifications and tests first published in 1934 are included, together with all proposed revisions of A.S.T.M. standards.

Part II: In addition to all of the formal papers presented at the 1934 meeting, Part II includes the extensive oral and written discussion.

The subjects covered by outstanding papers and discussion include: aging embrittlement of 4 to 6 per cent chromium steel; creep properties of chromium-molybdenum-steel still tubes; interpretation of creep tests; soil corrosion data; frictional resistance of steel and brass in shrink fits; strain measurements; and effect of test specimen on observed physical properties of steel.

Part I contains 1325 pages and Part II 943 pages, size 6 × 9. Price each part $5.50, heavy paper binding; $6.00 cloth; and $7.00, half-leather.

STEAM ENGINEERING ABROAD

As reported in the foreign technical press

Power from Refuse

The March issue of *The Power Engineer* (London) contains excerpts from the annual report of the Glasgow Cleansing Department concerning operation of the large refuse-burning power plant installed in that city. This plant contains two 5000-kw turbine-generators supplied with steam at 200 lb per sq in and 250 deg superheat from eight 6160-sq ft cross-drum water-tube boilers. The boilers are fired with pulverized refuse from which metal has been previously removed. Clinker and ashes are sold, as well as scrap metal, and a substantial revenue is received from the sale of power, all of which materially reduces the cost of operating the refuse-disposal plant.

For the fiscal year ending May 31, 1934, the equivalent of $144,000 was received for 40 million kilowatt-hours generated and about $60,000 from the sale of ash, clinker slabs and scrap metal. This reduced the total cost of refuse disposal to approximately $215,000 for the year.

The only difficulty reported is an abnormally large accumulation of dust in the combustion chambers. Steps are now being taken to reduce this. Also, a dust extraction system has been installed to eliminate dust dissemination during the handling of the clinker residue.

Boiler Tests on Two Large British Stoker-Fired Stations

Results of 24-hr boiler tests at the Deptford West Power Station of the London Power Company and at the Battersea Station of the same company are contained in the March issue of *The Fuel Economist.* The former contains three 375-lb pressure, 200,000-lb per hr (maximum continuous rating) boilers fired by multiple retort underfeed stokers and the latter six 615-lb pressure, 312,000-lb per hr (maximum continuous rating) boilers also fired by multiple retort underfeed stokers. Northumberland and Scotch coals, of 10,926 to 11,919 Btu per lb as fired, were used on the Deptford stokers and Scotch and Welsh semi-anthracite, having gross calorific values of 11,000 Btu and 13,500 Btu, respectively, were burned on the Battersea stokers.

In three tests at Deptford with an average output of 161,650 lb of steam per hour, using Scotch pea coal the overall efficiency, including boiler, water walls, superheater and economizer, averaged 88.7 per cent; the heat release per cubic foot of furnace volume per hour averaged 19,451 Btu; the coal per square foot of grate per hour averaged 36.7 lb; and the carbon in the refuse averaged 3.48 per cent. A 23-hr run at 202,175 lb per hr output, also using Scotch pea coal, gave an overall efficiency of 88.56 per cent, a heat release of 24,860 Btu per cu ft, 48.75 lb of coal per square foot of grate per hour and 4.5 per cent carbon in the refuse.

At Battersea a 25-hour test, with Scotch washed pea of 11,610 Btu per lb as fired and at an output of 257,794 lb of steam per hour, gave an overall efficiency of 89.46 per cent (86.98 per cent net efficiency), 38.6 lb of coal per square foot of grate per hour, 21,478 Btu per cu ft per hr heat release, and 5.43 per cent carbon in the refuse. A second test of approximately the same duration, with 260,613 lb of steam per hour, but having Rhymney Valley duff of 14,040 Btu per lb, gave an overall efficiency of 89.85 per cent (88.46 per cent net efficiency), 31.61 lb of coal per sq ft per hr, 21,272 Btu per cu ft per hr heat release, and 9.34 per cent carbon in the refuse.

Boiler Circulation

Die Wärme (Berlin) for January 26, contains a discussion of water circulation in steam boilers, in which the author disclaims that insufficient water velocity is responsible for overheating. Instead, it is usually caused by steam remaining too long in contact with the heating surface, as is the case where steam pockets are formed. Such pockets are more likely to form with high steam pressures and temperatures. The author cautions that throttling of circulation at the entrance to the drum be avoided, especially in boilers of the sectional header inclined-tube type; also that return-flow tubes be avoided.

With boilers having steeply inclined tubes it is believed that there is little danger of steam pockets being formed where the pressure does not exceed 285 lb per sq in.; at pressures up to 650 lb they are to be feared only in return-flow tubes in the front tube bank. With very high steam pressures, unheated downcomers are preferable.

Putting Standby Boilers on the Line

The practice of maintaining standby boilers ready for immediate use by supplying them with steam from boilers in service is by no means new, but some interesting tests at the Stettin power station, which employs this method are reported in *Die Wärme* of January 26. The boilers are stoker fired and have refractory furnace walls with long ignition arches. While being held in reserve the coal on the grate is kept moistened with oil and when it becomes necessary to put a unit on the line auxiliary oil burners are ignited electrically.

Tests on a boiler that had been off the line for several

weeks showed that the coal became ignited in 90 sec and in 8 min was burning sufficiently to permit turning off the auxiliary oil burners. Full rated output of the unit was reached in approximately two minutes from the time the oil burners were ignited. No trouble has been experienced from the sudden heating of the refractories.

Bulk Delivery of Pulverized Coal

Following a practice that has been developed extensively in Germany, two British firms have established large pulverizing plants at the collieries and are delivering pulverized coal in tank cars ready for use to steam plants and industrial furnaces. This pulverized coal, according to *The Steam Engineer* for March, is being sold under a guaranteed specification of volatiles (minimum) 35 per cent, ash (maximum) 4.5 per cent, moisture (maximum) 3 per cent, heating value 14,000 Btu per lb and a fineness of 95 per cent through a 100 mesh sieve. The delivered cost to the user, on a heat value basis, is said to be approximately half that of fuel oil.

Concentration Versus Pressure

Discussion of a paper on "The Care of Modern Steam Generating Plants from the Water Side" by R. T. Glinn, before the Institution of Mechanical Engineers, was reported in *Engineering* of February 22nd. This brought out that in a power station operating at 475 lb per sq in. pressure, excessive carry-over was encountered with a concentration of 150 gr per gallon. The trouble was eliminated by reducing the concentration to 70 gr per gallon. Another station operating at 375 lb per sq in. had to maintain the concentration at 50 gr per gallon in order to avoid carry-over; when the pressure was increased above this trouble was had at the same concentration. Another speaker considered that for 500 lb per sq in. a concentration of 100 gr per gallon was permissible and for 625 lb per sq in., 80 gr represented the allowable limit.

Propagation of Combustion in a Pile of Pulverized Coal

Fuel in Science and Practice, for February, cites some investigations on the propagation of combustion in stored pulverized coal. In the tests, tubes of different diameters were employed and a current of air was passed through the coal in the opposite direction to the wave of combustion. It was found that with a tube 2.5 cm. diameter, the composition of the oxidation product and the percentage of oxygen (namely, 11.2 in the case of bright coal and 12.5 with dull coal) was the minimum percentage in which propagation of a zone of combustion would proceed. The rate of combustion decreased with decreasing rate of flow of air and if the supply fell below one liter per hour the initial oxidation induced in the coal would not proceed throughout the mass.

Cinder and Fly Ash Measurement

A discussion by ARTHUR C. STERN
of P. H. Hardie's article in the March issue

The statement is made near the beginning of Mr. Hardie's article that cinder and fly ash measurements are conducted for one of three purposes: the determination of dust leaving the stack, the determination of the efficiency of dust separating apparatus and the determination of the combustible loss in cinders for use in the boiler heat balance. It is further stated that the "testing apparatus and testing technique required for these three investigations are essentially the same." The article then proceeds to describe a test method with the implied assumption that it satisfactorily meets the demands of all three types of tests. It is the purpose of this discussion to take issue with the quoted statement, and also with the implied conclusion.

To introduce the discussion, a short dissertation on the subject of the stratification of dust laden flue gases in ducts is necessary. This is the bugaboo of dust measurement. There are many who question the value of developing improved dust measuring apparatus, while the proper placing of the sampling tube still remains unpredictable to a certainty. However, this unpredictability is rapidly disappearing as more and more test results become available for study, such as the valuable data published in the article under discussion. An analysis of this data will prove useful. It represents samples from twelve sampling locations in a rectangular duct, arranged in three rows of four each (or conversely of four rows of three each). There is virtually no flue gas velocity variation (stratification) longitudinally, in the four-row direction; however, laterally, in the three-row direction, velocity increases across the duct width in the ratio for the three rows of 1.00:1.90: 2.25. To an experienced observer, the prediction regarding dust loading that can be drawn from these facts concerning gas velocity are that no appreciable stratification should appear longitudinally, and that loading should be stratified laterally in the same directional sense that velocity is stratified.

In drawing these inferences there is one major source of error of which we must be wary; that is, that some previous obstruction (or turn of the duct at right angles to the turn or obstruction which caused the major lateral stratification) may have caused a substratification of heavy particles longitudinally, close to one of the duct walls. The bulk of the loading will not, however, be seriously affected by this heavy particle stratification, since, as will be indicated in data presented later, these heavy particles usually do not constitute as large a proportion of the total as the data in the article under discussion would indicate. There are, however, no evidences of heavy particle stratification longitudinally in any of this data.

The average dust loading computed for each row in the lateral direction shows the dust loading per row to be 0.0026 lb per lb, 0.00123 lb per lb and 0.00061 lb per lb, respectively, with practically no dust loading variation longitudinally. As previously noted, this could have been largely predicted from the pitot tube traverse. A twelve-point dust loading traverse may be justified in order to check these predictions, but in subsequent tests substantially as high accuracy can be obtained by a three-point traverse laterally. Such a three-point traverse can give all the necessary information with much less cost and work than a full twelve-point traverse under similar flue gas velocity conditions. In such a case, it is possible to go even one step further, and, for routine testing, find one spot in the duct which will give results representative of the entire duct. If the pitot tube traverse of the duct remains substantially the same during subsequent tests at any given boiler rating, and if a reasonably good twelve-, six- or three-points traverse has been made of the duct, then from this data, the proper spot from which the sample should be withdrawn may be readily calculated.

However, in calculating the mean dust loading from a multipoint traverse (which is a necessary preliminary to determining the spot where it can be measured), the dust loading in each different

(*Continued on page 38*)

Cinder and Fly Ash Measurement

(*Continued from page 37*)

flue gas strata should be weighted by the relative flue gas velocity. In the data under consideration, the far row of sampling holes shows 4.25 times the dust loading and 2.25 times the velocity of the near row. Since they represent the same duct areas, that means that the far section of the duct is carrying $4.25 \times 2.25 = 9.56$ times as much dust as the near section per unit of time. This fact cannot be accounted for unless the dust loading data be weighted by the velocity data. In the paper under discussion, the average dust loading for the duct appears to have been determined without such weighting, which the writer believes to be an erroneous procedure.

If the dust loading for each of the twelve sampling locations be determined and then averaged without weighting, the average dust loading for the duct is 0.00148 lb per lb. When each of these individual loadings is properly weighted by the velocity, the loading for the duct becomes 0.00173 lb per lb, which by a most curious coincidence is the same loading arrived at in the article by the process of dividing the total pounds of sample collected by all twelve sampling tubes by the total pounds of gas sampled by them.

All this is by way of introduction to the writer's contention that both the multi-point duct traverse and the single-point sample, in which one sampling tube withdraws a sample representative of the duct, have their proper sphere of use in dust measurement, and that these spheres rarely overlap each other. The conditions under which the multi-point traverse should be used are dust separator acceptance tests or tests on ducts where the pitot tube traverse shows an unpredictable variation of dust loading. This last really means the initial tests of very large ducts generally.

The conditions under which one-point samples are preferable are to obtain the cinder loss for heat balance in routine boiler tests on the same duct time after time, and for cinder emission studies under the same conditions. The reason for this distinction is that the single-point sample means much less work, cost and time in running the test, and brings cinder testing more in the class of the hand Orsat as regards usefulness. In the interest of better boiler testing and better heat balances, it is important that the cinder test be made easy to run, especially since the cinder loss frequently exceeds the CO loss. From the operating man's viewpoint, frequent cinder samples are a great aid to the proper setting of burners and to regulation of stokers. In fact, in one plant, to the writer's knowledge, a continuous one-point sample is withdrawn all the time the boiler operates. This is, at regular intervals, compared with a calorimetric scale of combustible content in order to maintain burner adjustment.

If, as the writer contends, there are certain types of tests in which a one-point sample should be used rather than a multi-point test, then this fact affects the type of test equipment that must be used. To get reasonable accuracy of weighing the sample and measuring the gas, about 750 cu ft[1] of gas must be sampled. To do this with the woolen bag method described in the article, which in the tests described operated at an average sampling rate of 3.60 cu ft per min, would take about $3^1/_2$ hr. This appears entirely too long a test duration for the type of test for which the one-point sample is recommended, namely, routine boiler testing and to get operating information. This long duration would, of course, not be unreasonable for a cinder catcher acceptance test, therefore this is the type of test for which these woolen and monel mesh bags are most adaptable.

The writer has already placed himself on record[2] as favoring for one-point samples the use of a high efficiency cyclone dust collector as a test method. In this method up to 50 cu ft per min of flue gas is sampled so that the test duration is only about 15 or 20 min, which is a reasonable time for routine boiler plant use.

In comparing the woolen bag test method with the cyclone test, it should be noted that the cyclone leaves all of its sample in a glass Ehrlenmeyer flask available for subsequent chemical analysis or sizing, whereas part of the woolen bag sample must of necessity be lost in the bag itself and in the act of emptying the bag into the screens or crucibles. In this connection, it is interesting to compare the 10.9 per cent through 325-mesh screen of the inlet dust sample noted in the article with the 30 per cent or more through 325 mesh that the writer was accustomed to obtain from his cyclone test samples of cinder from bituminous coal, underfeed stoker fired. This difference may or may not be due to shortcomings of the mesh filter test method.

There is but one other point that will be discussed. The article states that a dust loading test can be interrupted, if necessary, by stopping the flow of gas just ahead of the source of suction. Such a procedure, in the writer's opinion, should be sufficient to invalidate a test, because all the while the flow of gas is stopped, heavy cinder particles are being projected into the sampling tube by their own inertia, thus "peppering" the sample, and making it heavier than it normally should be. Of course, on a test of 3 hr duration there is no other alternative to the above procedure; but if anything should occur to balk a cyclone test there are two alternatives. If the test has run for more than 10 min, it can be stopped and considered as a complete test run; while if the run has been for less than 10 min, the run can be abandoned with only 10 min loss, and a new test run started.

In conclusion, the writer desires to repeat the contention that there is no one all inclusive test method for dust loading and if there were such a test method, the cyclone test would come closer to qualifying than the various small bag filter methods that have been proposed and used from time to time.

[1] All gas measurements at 60 F—30 in. Hg.
[2] The Measurement and Properties of Cinders and Fly Ash by A. C. Stern, June-July 1933, COMBUSTION, p. 35.

EQUIPMENT SALES
Boiler, Stoker, Pulverized Fuel

As reported by equipment manufacturers of the Department of Commerce, Bureau of the Census

Boiler Sales

Orders for 116 water-tube and h.r.t. boilers were placed in January and February

	Number	Square Feet
January, 1935	56	199,196
February, 1935	60	195,025
January to February (inclusive, 1935)	116	394,221
Same period, 1934	98	284,995

NEW ORDERS, BY KIND, PLACED IN JAN. AND FEB., 1934–1935

Kind	Jan., 1934 Number	Jan., 1934 Square feet	Feb., 1934 Number	Feb., 1934 Square feet	Jan., 1935 Number	Jan., 1935 Square feet	Feb., 1935 Number	Feb., 1935 Square feet
Stationary:								
Water tube.	22	96,695	31	129,191	41	181,087	40	179,207
Horizontal return tubular.....	24	35,030	21	24,079	15	18,109	20	15,818
	46	131,725	52	153,270	56	199,196	60	195,025

Mechanical Stoker Sales

Orders for 244 stokers, Class, 4* totaling 45,503 hp were placed in January and February by 68 manufacturers

	Installed under: Fire-tube Boilers No.	Fire-tube Boilers Horsepower	Water-tube Boilers No.	Water-tube Boilers Horsepower
January, 1935	103	13,273	36	11,066
February, 1935	68	8,717	37	12,447
January to February (inclusive, 1935)	171	21,990	73	23,513
Same period, 1934	169	20,245	48	19,832

* Capacity over 300 lb of coal per hr.

Pulverized Fuel Equipment Sales

Orders for 17 pulverizers with a total capacity of 67,150 lb per hr were placed in January and February

STORAGE SYSTEM

	Pulverizers: Total number	No. for new boilers, furnaces and kilns	No. for existing boilers	Total capacity lb coal per hour for contract	Water-tube Boilers: Number	Total sq ft steam-generating surface	Total lb steam per hour equivalent
January, 1935	..	..	..	....	..	...	....
February, 1935	..	..	..	....	..	...	....
January to February (inclusive, 1935)	..	..	..	....	..	...	....
Same period, 1934	..	..	..	....	..	...	....

DIRECT FIRED OR UNIT SYSTEM

	Pulverizers				Water-tube Boilers		
January, 1935	5	1	4	9,590	5	15,724	103,680
February, 1935	12	8	4	57,560	12	75,967	543,000
January to February (inclusive, 1935)	17	9	8	67,150	17	91,691	646,680
Same period, 1934	10	7	3	56,000	8	54,706	449,200
					Fire-tube Boilers		
January, 1935	..	..	..	....	..	....	.....
February, 1935	..	..	..	....	..	....	.....
January to February (inclusive, 1935)	..	..	..	....	..	....	.....
Same period, 1934	2	..	2	2,400	2	3,000	20,500

Conventions and Annual Meetings of Engineering Societies

April 18–19—Southeastern Section Edison Electric Institute, Forest Hills Hotel, Augusta, Georgia

April 22–26—American Chemical Society, Hotel Pennsylvania, New York, N. Y.

April 24–25—Combustion Engineering Division of Association of Iron & Steel Electrical Engineers, Ohio Hotel, Youngstown, Ohio

May 6–8—Master Boiler Makers Association, Chicago, Illinois

May 6–10—American Water Works Association, Annual Meeting, Cincinnati, Ohio

May 14–16—American Petroleum Institute, Mayo Hotel, Tulsa, Oklahoma

May 20–21—Heating, Piping & Air Conditioning Contractors, Hotel Gibson, Cincinnati

June 3–6—Edison Electric Institute, Annual Convention, Washington, D. C.

June 4–7—American Smoke Prevention Association, St. Louis, Mo.

June 5–7—American Pulp & Paper Mill Supt. Association, John Marshall Hotel, Richmond, Virginia

June 11–14—National District Heating Association, Annual Meeting, Bellevue-Stratford Hotel, Philadelphia, Pa.

June 19–21—A.S.M.E. Summer Meeting, Hotel Gibson, Cincinnati, Ohio

June 17–19—American Society of Heating & Ventilating Engineers, Toronto, Canada

June 24–28—A.S.T.M. Annual Meeting, Book-Cadillac, Detroit, Michigan

June 25–27—Great Lakes Power Show (S.S. *Seeandbee*, Buffalo, June 25, Cleveland, June 26, Detroit, June 27)

July 8–12—American Society of Civil Engineers (Summer Meeting), Los Angeles, California. Date tentative

Aug. 26–30—National Association of Power Engineers, William Penn Hotel, Pittsburgh (Exposition in conjunction with meeting)

Sept. 16–21—Midwest Power Show, Coliseum, Chicago

Sept. 24–26—Association of Iron & Steel Electrical Engineers, William Penn Hotel, Pittsburgh, Pa.

Sept. 30–Oct. 4—American Welding Society Annual Meeting, Chicago, Ill. (Date tentative)

Dec. 2–5—A.S.M.E. Annual Meeting, New York, N. Y.

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